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ART. XXIX. — *Recent Explorations in the Wappinger Valley Limestone of Dutchess County, New York;* by Prof. WILLIAM B. DWIGHT, Vassar College, Poughkeepsie, N. Y. With Plate VII.

No. 4.—DESCRIPTIONS OF CALCIFEROUS (?) FOSSILS.

IN a previous paper of this series, four years ago,* the writer made known his identification of Calciferous, as well as Trenton rocks, in the limestones of the Wappinger Valley. This determination was founded on the presence of the ordinary but very unsatisfactory fossils considered characteristic of the Calciferous in the United States.

One year later announcement was made, in a brief note,† of his further discoveries, in the same apparently Calciferous stratum, of fossils far more striking and important. These were stated to be gasteropods and one or two small brachiopods, accompanying orthoceratites lying crowded together, in some localities, and in much variety of structure and of size, reaching in some cases a length of 9 inches, and in others a width of $1\frac{1}{2}$.

The long interval which has followed without the publication of the details in this series of papers has been unavoidably due to the extent of the problems, and of the work, thus suddenly and unexpectedly presented. The question of the true age of the stratum was at once re-opened; new, careful and extended exploration for all attainable facts was imperatively

* This Journal, January, 1880. † This Journal, January, 1881.

demanded. Under this exploration the stratigraphic relations of the adjacent slates and the two limestone formations, which at first seemed simple, proved exceedingly complicated; a large mass of fossils in a highly fragmentary and considerably metamorphosed condition has been collected, from which definite results in determination could be reached only by the most delicate and laborious manipulation, and the most painstaking collation of forms. This field work is not yet concluded, for every excursion, while contributing perhaps to the solution of previously unknown quantities, has brought forward new problems.

On account of the richness of this field in facts of paleontological and stratigraphical importance, it is now evident that justice cannot be done to the subject within the limits of these papers. The general facts, however, of both the stratigraphy and paleontology of this limestone belt will be presented here, leaving the more complete discussion of the subject for a monograph which the writer designs to prepare as soon as the work of investigation can be sufficiently completed. The Trenton limestone present has already furnished additional fossils, of which descriptions will hereafter be given.

The particular object of the present paper is to begin the descriptions of Calciferous (?) fossils. Before describing them, however, it will be proper to add a few very brief statements, sufficient for the present purpose, as to their occurrence and the probabilities as to their age.

What I am prepared to say at present in regard to their relative age may be stated as follows:

I. The rock containing them, both in its lithological character and its fossils, is quite distinct from the super-jacent limestone which is beyond question Trenton.

II. Its orthoceratites differ notably from any similar collection, taken as a whole, as far as I know, in either the Trenton or the Black River groups, in the facts that no species are found among them whose septa are more distant than about nine to the inch, most of them having septa standing much more closely; and the additional feature that with the rarest exceptions the siphons are lateral, if not marginal, with a tendency to be proportionally very large throughout the group.

III. Everywhere closely intermingled with the orthoceratites are various gasteropods appearing to be identical with those accounted characteristic of the Calciferous of the United States and of Canada. Notably there are admirable specimens of the *Ophileta compacta*, fortunately fully described and illustrated by Salter. (Geological Survey of Canada, Decade I, p. 16.) Except for the presence of these orthoceratites, there would be no hesitation is assigning this limestone to the so-called

Calciferous group. But the presence of these new fossils, to say nothing of existing doubts as to the true stratigraphic relations of much that has elsewhere been called Calciferous, suggests great caution in deciding upon the horizon.

On the other hand, these fossils as a whole, cannot at present be safely assigned to any other group with so much justification as to the Calciferous. They will be so assigned at this time, but with the understanding that it is a provisional arrangement.

A more full discussion of the age of this rock will be appropriate after the fossils have been more fully described, including the important gasteropods above mentioned.

This Calciferous formation, accompanied in many places by the Trenton in much smaller masses, displays its fossils for a number of miles above and below Poughkeepsie, in the Wappinger Valley. By far the richest locality, however, is at the hamlet of Rochdale; especially are the orthocerata the largest, and the most crowded together in a low ledge on a hill-side about 900 feet northwest of the woolen mills.

I am much indebted to the kindly and most valuable assistance of Mr. R. P. Whitfield in the difficult study of the specimens as well as in the drawing of some of the figures. Figures 1, 1*a*, 4 and 5 were outlined by him from the type specimens.

In my descriptions of Rochdale fossils, the richly fossiliferous ledge exposed for 200 or 300 feet each side of the cross-wall between the farms of H. Titus and W. Badgely, about 900 feet northwest of the woolen mill, will be named D. Another Calciferous locality, next to the one just mentioned in paleontological importance, designated F, consists of a series of outcrops barely above the surface of the ground in W. Badgely's field extending from the northerly extremity of ledge D, between two hills, to the Pleasant Valley turnpike, with which it is about on a level throughout. This locality is specially rich in small and neat annulated and other orthocerata, while the ledge D is filled with the larger Cephalopods.

Crustacea.

Quite a number of fragments of trilobites have been collected at locality D. One which is a portion of a thickened margin of a cephalic shield, is 5^{cm} long and 13^{mm} wide. But the fragments which are sufficiently well preserved to admit of specific description are small, belonging to animals probably 5^{cm} or under in total length. The cephalic shields of the two species here described are not sufficiently complete to justify a satisfactory decision as to the genus. The courses of the facial

sutures are especially incomplete. While they in many respects strongly resemble Bathyurus, they do not appear in all points to conform to that type. For the present, however, they will be provisionally classed under that genus.

Bathyurus taurifrons, n. sp.

Figs. 1, 1*a*, 2, 2*a*, 2*b* and 3.

Glabella very convex, much elevated, slightly conical, the sides of its posterior two-thirds being nearly parallel, while its anterior third is a little narrowed, and then rounded in front. Its greatest width is two-thirds of its length exclusive of the occipital ring. There is a slight, yet evident longitudinal line of angularity along the summit, and there are three pairs of very faint transverse furrows extending from the sides obliquely backward for about one-third of the width of the glabella. Certain traces may perhaps indicate a fourth pair situated more anteriorly. The three pair first mentioned are so situated that lines joining the outer ends of each pair would divide the surface nearly into quarters. With the above exceptions the glabella is entirely smooth.

The summit of the glabella is about its greatest width (and its anterior border about half the same), above the level of the anterior edge of the cephalic shield. In the specimens described this summit elevation is $7{\cdot}5^{mm}$. From the anterior dorsal furrow the surface of the cephalic shield descends in a steep sigmoid curve to its anterior margin which projects in a horizontal distance beyond the glabella about one-third of the maximum transverse diameter of the latter.

The dorsal furrow extends entirely around the glabella, but is not very deep. The anterior limb of the cephalic shield is about one-third wider than the glabella. The fixed cheeks are narrow; the palpebral lobes (not thoroughly preserved in the specimens), are small and opposite the center of the glabella. The occipital furrow is well marked and extends the entire glabellar width; the occipital ring has a longitudinal axis about one-sixth that of the glabella, and extends laterally a little beyond the dorsal furrows. Movable cheeks and thoracic segments not known.

Pygidium, anterior margin a gentle curve, posterior and lateral margin semicircular. The axial lobe well defined, in front one-third of entire width of pygidium, tapering considerably to the rounded posterior termination which does not quite attain the junction posteriorly of the lateral lobes; its length is two-thirds that of the entire pygidium. It is quite convex transversely, while it also curves rapidly down from front to rear. Its surface is without furrows and quite smooth, excepting a slight angularity along the median line of its summit,

and two tubercles situated close together at its posterior terminus. The lateral lobes are less convex than the axial, and marked by three or four faint furrows, some of which may be traced across the margin by close inspection.

The depressed marginal band is rather wide, being about one-eighth of the greatest width of the pygidium; it is but little narrower at the extreme posterior portion.

The elevation of the anterior portion of the axial lobe above the marginal edge of the pygidium, is nearly equal to the greatest width of that lobe; about 4^{mm} in present specimens.

On account of the disappearance of all thoracic portions in specimens, the connection of the above described pygidium with the cephalic shield described, can only be inferred from their frequent occurrence intermingled in close proximity. These occurrences seem to justify the decision of the identity of the species. There is much general resemblance between this species and *Bathyurus extans* of the Trenton. Yet there are marked differences, such as the remarkable elevation of the glabella in the new species, while the pygidia vary in many features.

Locality—Calciferous, Ledge D, Rochdale.

Bathyurus? crotalifrons, n. sp.

Figs. 4, 4*a*, 5 and 6.

Glabella low, convex, strongly conical, its sides being somewhat concave a little anteriorly of the center. Its maximum width is very little less (about $\frac{1}{14}$) than its length exclusive of the occipital ring, and is found at about one-sixth of this length anteriorly to the occipital furrows. In the anterior third, the transverse diameter diminishes to two-thirds of the maximum and less. The front border and the posterior angles are well rounded. Surface of glabella is covered with tubercles; there are no glabellar furrows; dorsal furrows extend quite around, and are very deep; occipital furrow well-marked and extending across the entire breadth of the glabella; the tuberculated occipital ring has its longitudinal axis at least $\frac{1}{5}$th that of the glabella in front of it, while its width scarcely equals that of the glabella. Fixed cheeks of moderate width; these, and the palpebral lobes, depressed convex, the latter carrying a broad shallow groove at the exterior margin over the eye. The anterior margin of the cephalic shield projects in front of the glabella to a distance equaling about one-fifth of the length of the latter, exclusive of the occipital ring. The posterior limb of the cephalic shield extends out laterally at nearly right angles to the longitudinal axis.

Movable cheeks low convex, tuberculated, with a rounded lateral margin; ocular sinus moderate. General outline of

cephalic shield not thoroughly defined in the specimens. Thorax and pygidium unknown.

Locality—Calciferous. Ledge D, Rochdale, N. Y. Fragments of half a dozen individuals found.

Cephalopoda.

Cyrtoceras Vassarina, n. sp.

Figs. 7, 7*a* and 8.

Shell stout, large and smooth, varying in the same individual from 1^{mm} to 2^{mm} in thickness; considerably curved in most specimens; the transverse-section is more or less distorted by compression in the best preserved specimens, but it appears to be broadly elliptical, the transverse axis being a little less than one-fifth shorter than the dorso-ventral axis. Taper gradual, about one part to nine near the chamber of habitation.

Septa from 10 to 15 or more to the inch, deeply concave, the concavity exceeding by one-half the depth of the interseptal spaces; their marginal sutures but slightly curved along the lateral margins, arching somewhat forward toward the concave ventral margin, and very strongly forward toward the convex dorsal margin. The extent of this forward deflection near the dorsal and siphuncular side, about equals three of the interseptal spaces, while that near the ventral side is somewhat less than one interseptal space. In several of the most marked specimens, the line joining in a cross-section, the points of maximum deflection to the front, on the opposite margins (shown by the dotted line in fig. 7*a*), would show a considerable angular deviation from the dorso-ventral line.

Siphuncle marginal, somewhat flattened, and of moderate proportional size, which is probably somewhat variable in different individuals of the species. In the specimen described in which it is best shown, fig. 8, its greatest diameter (parallel to the margin) is 4^{mm} and its transverse diameter about $\frac{1}{15}$ less, where the shell has a dorso-ventral diameter of 29^{mm}. In the other specimen (fig. 7) the siphuncle appears to have about the same proportion near the chamber of habitation, and nearer the apex it has a maximum diameter of 2^{mm} where that of the shell is two decimeters. In some specimens at least (as shown in fig. 7*a*) the siphuncle, which is dorsal, is situated considerably to one side of the dorso-ventral axis. It is slightly beaded, the gentle expansions occurring where it is met by the very oblique edges of the septa.

The chamber of habitation is capacious. Locality—Calciferous, Rochdale, N. Y., throughout the fossiliferous layers, but especially at Ledge D.

This is one of the most prominent and abundant of the orthoceratites in the Wappinger Creek valley; it occurs mostly in small fragments, sometimes closely crowded together; the largest known specimens have an incomplete length of five or six inches, implying a complete one of eight or nine inches. Several orthocerata of the latter length have been collected which are probably referable to this species, but lack of evidence as to the septa and siphuncle leaves the question at present in doubt. Although the specimens here described, and many similar ones, appear to belong under "Cyrtoceras," yet there is reason for doubt on this point. This arises from the presence of quite a number of orthoceratites closely resembling these, as far as can be judged in their imperfect state, but which are nearly or quite straight. It is possible that this latter group on further examination may disclose a specific difference in the shape of the cross-section, and especially in the rate of increase in the diameter of the shell which seems to differ from the taper above described. A local name has been assigned in honor of the college in whose vicinity these specimens occur.

Cyrtoceras? dactyloides, n. sp.

Figs. 9 and 9*a*.

Shell small, slender, tapering about $\frac{1}{5}$th to the inch; gently curved; surface not known, except so far as it appears smooth in vertical section; transverse section (of which only about three-fourths is evident) apparently elliptical, with the proportions of six to five for the two axes.

Septa about seventeen to the inch, considerably concave, the concavity equaling the depth of the interseptal spaces; their sutures horizontal at the lateral margins and very slightly curving forward at the dorsal margin; they are not preserved in the specimen at the ventral margin, but the partial obliquity in the position of the septa shown in the longitudinal section (upper half of fig. 9) indicates more arching forward on the ventral than on the dorsal side.

Siphuncle marginal, very nearly circular, there being a barely perceptible flattening parallel to the margin: it is on the convex dorsal side, and is proportionally large for a *Cyrtoceras;* its gain in size is apparently more rapid than that of the shell, for at the smaller end its diameter is slightly more than 2^{mm}, or one-fourth the diameter of the shell at that point, while at the larger end, its diameter is $3{\cdot}75^{mm}$ or about one-third the whole diameter of that portion. This species bears considerable resemblance to *Orthoceras sordidum* Billings (Can. Nat. and Geol., vol. iv, Calciferous group), yet the Canadian fossil, the type specimen of which, by the kindness of

Mr. J. F. Whiteaves, I have been able to examine, differs in several points, as lack of curvature, less proportional size of siphuncle, different shape of cross-section, stronger forward arching of the septa near the siphuncle, and other features. Locality—Calciferous, Ledge D, Rochdale, N. Y.

Cyrtoceras microscopicum, n. sp.

Fig. 11.

Shell very small and with exceedingly thin, delicate walls. It is known only in the exhibition of a longitudinal section of a single specimen. It is much curved on the inner margin, and very moderately on the outer one; its taper is apparently very rapid, but as some of this appearance may be due to possible obliquity of the section, no definite rate can be stated. Septa extremely delicate and crowded together at the rate of about 96 to the inch, with a gentle concavity, and meeting the dorsal and ventral margins at the same level. Neither the siphuncle nor the cross-section are known. The only specimen collected has a length of $6{\cdot}5^{mm}$, while the transverse diameters at the extremities are respectively 5^{mm} and 3^{mm}.

Locality—F, Calciferous, Rochdale, N. Y.

Orthoceras spissiseptum, n. sp.

Fig. 12.

Shell quite small, slightly curved, thin, and apparently nearly cylindrical. As the only specimen collected presents merely a plane longitudinal section, more or less oblique, the rate of taper cannot be stated more exactly. Septa delicate and exceedingly close together, at the rate of about 95 to the inch; their concavity is considerable, after making all possible allowance for obliquity of the section; their junctions with the shell are evidently considerably higher on one side than on the other. Transverse section, and siphuncle unknown. The fragment of the only specimen collected is $10{\cdot}5^{mm}$ long, and about 6^{mm} in transverse diameter.

Locality—Calciferous, Ledge D, Rochdale, N. Y.

Orthoceras Henrietta n. sp.

Figs. 13, 14 and 14*a*.

Shell small and tapering gently, at an approximate rate of one to ten, annulated, with generally from eight to ten rings to the inch (in some instances only six); these annulations are always formed more or less by undulations of the entire body of the shell, which is quite variable in thickness in different places; but frequently the rings are increased by a thickening of the shell where they occur. Chamber of habitation long;

it is apparently contracted anteriorly in several specimens, all of which are longitudinal sections made by natural weathering. This apparent contraction may be due to obliquity of the sections, or to curvature. No specimen has yet been collected that gives any other view of the fossil than a sectional one. Septa delicate and frequent, usually from twenty to thirty to the inch, though some have more; they are gently concave, and some of the natural sections exhibit them in positions where they indicate some obliquity of suture.

The imperfect transverse section, fig. 14*a*, exhibits an elliptical outline; a more complete one, since obtained, reveals an ellipticity of three to one, much greater than that indicated in this figure.

Siphuncle lateral, but probably not marginal, circular, with a diameter of a little less than a millimeter ($\frac{1}{32}$ inch), where the shell has a diameter of $6{\cdot}3^{mm}$. Locality—Calciferous, one or two specimens at Ledge D, but chiefly at locality F, Rochdale, N. Y.

I have thought it proper to give these graceful orthocerata a specific name in honor of Mrs. Henrietta Manning of New York City, since her generous contributions toward the expenses of developing this field of paleontological research have much facilitated the work and have constituted her a patron of science.

Oncoceras vasiforme, n. sp.

Figs. 10 and 10*a*.

The description of this fossil is derived from a single specimen which is half imbedded, longitudinally, and the other half is lost by abrasion. There is thus exhibited only a plane median vertical section, nearly, but not quite, at right angles with the dorso-ventral axis. Shell small and delicate (4^{cm} in length and 9^{mm} maximum width), amount of curvature unknown, ventricose at the upper parts of the septate portion, and the lower part of the chamber of habitation, very narrow in the lower septate portion; chamber of habitation large, its length being more than one-third of the estimated length of the shell. Its maximum transverse diameter is anterior to the last septum at a distance of about one-fourth the diameter of the latter. Anteriorly, it then narrows to the aperture (whose diameter is about one-fourth of the maximum), rather evenly and gently; one margin in the vertical section exhibited, is convex externally throughout to the aperture, the other margin is convex for about one-half the distance and then gradually changes into a gentle concave line, showing a special but slight constriction on that side near the front.

From the above mentioned position of maximum ventricosity in the chamber of habitation, the shell diminishes with a rapid taper posteriorly to the apex. At the distance, however, of eight or nine septa from the first one, the rate of taper, which up to that point has been as one to three, diminishes a little for the remaining apical portion, causing a slight concavity in the outline in that vicinity.

A cut made across this fossil 4^{mm} anterior to its posterior termination, reveals one (dorsal ?) half of the transverse section, and shows that the complete section must be a little elliptical (if not ovate). The siphuncle, which is shown in this section near the end of the longer axis of this semi-ellipse, is very small, with a diameter of $\cdot 65^{mm}$ where the shell has a diameter of 6^{mm}; it is circular and quite close to the shell, though not actually in contact. The septa are frequent, about twenty-three to the inch, two or three nearest the chamber of habitation standing much closer together. They are very gently curved, and seem slightly oblique in this section. Locality—Calciferous, ledges in field F, Rochdale, N. Y.

This fossil sufficiently resembles *O. mummiforme* Whitfield (Geol. Wis., vol. iv, p. 232), to have induced for awhile its assignment to that species. A critical comparison however has made this assignment doubtful, and the recent evidence obtained in the cross-cut of the position of the siphon removes all doubt that it is a distinct species. It is certainly no nearer to *O. constrictum* Hall, and appears to be new.

EXPLANATION OF PLATE VII.—WAPPINGER VALLEY FOSSILS.

All the specimens here illustrated are from the Calciferous (?) at Rochdale, N. Y., and are represented in their natural size.

BATHYURUS (?) TAURIFRONS.

Fig. 1. Glabella and fixed cheeks, the former showing the furrows and median angular line. The furrows appear much too conspicuous in the cut.

Fig. 1*a*. Profile view of the same specimen.

Fig. 2. A pygidium found in close proximity to the above, probably of the same species, if not of the same individual.

Fig. 2*a*. Vertical transverse section of the same, showing the elevation and transverse contour of the anterior limb.

Fig. 2*b*. Profile view of same pygidium.

Fig. 3. Pygidium of another individual of same species, showing distinctly the two posterior tubercles on the axis.

BATHYURUS (?) CROTALIFRONS.

Fig. 4. View of a gutta percha cast taken from a natural mould, showing the glabella and fixed cheeks.

Fig. 4*a*. Profile view of same.

Fig. 5. View of gutta percha cast of natural mould of the right movable cheek of a larger specimen of the same species, showing the ocular sinus.

Fig. 6. View of glabella and a small portion of fixed cheeks of another individual. The parts represented on the right side of the glabella, especially the arcuated line, are doubtful, belonging perhaps to some other individual.

ORTHOCERAS VASSARINA.

Fig. 7. Lateral view of an internal cast, carrying portions of the smooth shell, showing clearly the chamber of habitation, septal sutures, and curvature of the septa. The smooth surface to the right below, has been polished to show the siphuncle which appears in the figure.

Fig. 7*a*. Transverse section of upper portion of same, showing the position of the siphuncle (not seen in that part of fig. 7) considerably to one side of the dorso-ventral axis. The upper part of this section shows a distortion by flattening. The broken straight line connects the points of maximum forward deflection of the septal sutures.

Fig. 8. Dorsal view of internal mould (with portion of shell) of another individual, showing the upward arching of the septa, and the marginal siphuncle a little expanded at its points of junction with the septa.

CYRTOCERAS DACTYLOIDES.

Fig. 9. A well defined specimen, the lower third of which is the cylindrica internal mould, showing the sutures, while the upper two-thirds is an abraded and polished vertical plane section of the same, showing the large marginal siphon, and the curvature of the septa.

Fig. 9*a*. A transverse section at the lower end, showing the size of the siphuncle at that point.

ONCOCERAS VASIFORME.

Fig. 10. A natural vertical median plane section, not quite rectangular to the dorso-ventral axis.

Fig. 10*a*. An artificial transverse section of the specimen, 4^{mm} from the lower end, showing the position of the siphuncle.

CYRTOCERAS MICROSCOPICUM.

Fig. 11. A polished vertical median plane section passing probably nearly in the plane of the dorso-ventral axis.

ORTHOCERAS SPISSISEPTUM.

Fig. 12. A natural longitudinal section, showing a few of the septa.

ORTHOCERAS HENRIETTA.

Fig. 13. A polished vertical section showing the chamber of habitation, and some of the septate portion.

Fig. 14. A similar, somewhat oblique section of another individual, showing the siphuncle at lower end.

Fig. 14*a*. A polished transverse section of the lower end of the same showing the position of the siphuncle.

ART. XXX.—*Upon the Kettle-Holes near Wood's Holl, Mass.*; by Professor B. F. KOONS.

IN the study of the glacial phenomena about Wood's Holl, Mass., I have gathered many facts concerning the Kettle-Holes of the region as to depth, size, direction of the longer axis, their groupings, and other points, which may throw light upon their origin. No special study of them as regards some of these points had been made, and, therefore, without previous convictions as to what conclusion the facts would lead, I determined during the last summer to give them a careful examination as far as my work in connection with the United States Fish Commission at Wood's Holl would allow. Professor Warren Upham, who has made many observations on the terminal moraine along southern New England and the adjoining islands, regards the deposits as a part of that terminal moraine, and others hold the same opinion. There is perhaps no more remarkable region on the whole line than the vicinity of Wood's Holl, both over the point of the main-land, and on the adjoining eastern islands, Uncatina, Nonamesset, and Naushon, of the Elizabeth group, which extend southwestward between Buzzard's Bay on the north and Vineyard Sound and the ocean on the south. The trend of this group of islands is north 60° east.

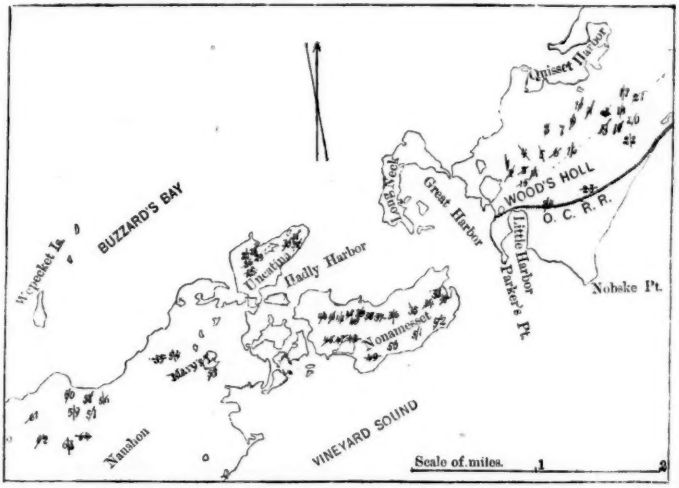
The hills are masses of earth, sand, gravel and bowlders tumbled together in the greatest confusion. In places the surface is well covered with granite and gneiss bowlders, some of gigantic size, as will be seen by reference to table No. 2.

The theory that this is a part of the terminal moraine, seems plausible when the country is viewed from some of the high hills a mile or two to the east of Wood's Holl. To the southwest stretches away the long line of islands; and to the northeast almost as far as Falmouth, it appears as though the glacier had pushed its front down to the sea and there unloaded its vast amount of rock and earth to form this line of abrupt hills. To the northeast of Falmouth, these hills recede from the coast, leaving a level plain between them and the sea. For a number of miles the railroad runs along the base of these hills, leaving the level tract of country to the southeast of it; while to the northwest are the high and rugged hills of unstratified material.

Upon the tops of some of these hills (of the peninsula of the main-land) one hundred or more feet above the level of the sea where cuts for roads have been made, *stratified* material, consisting of sand and gravel is found. This occurs between Buzzard's Bay and Vineyard Sound, where the land is not more than three-fourths of a mile wide. One of these localities of stratified material is directly on the north side of a kettle-hole

(No. 18 on the map below) upon the steep border, seventy-three feet above the bottom.

At another place, upon a similar deposit several feet thick, lies a bowlder weighing several tons. On the island of Naushon, opposite Tarpaulin Cove, upon the summit of a hill over 200 feet above the sea-level and where the island is not more than two-thirds of a mile wide, there is a stratified deposit which has been partly cut away by the winds and thus its character made known. It has at top a bed of fine yellow sand ten inches thick; beneath this a layer of white or smoky white sand, then again a black layer, and beneath this a ferruginous layer two inches thick, all very similar to those of Gay Head at the west end of Martha's Vineyard. And within a few rods of this stratified deposit the surface over a considerable area is completely covered with bowlders, two of which, Nos. 7 and 8 of table No. 2, are of unusual size.



Map of the vicinity of Wood's Holl and the neighboring Elizabeth Islands, showing positions and direction of the larger diameter of the Kettle-Holes.

In my study of this region I kept a record generally of only the largest kettle-holes—passing by some of great size because they are so very numerous. It seemed important to obtain measurements of a representative number, and these sufficiently distributed to give the general character of the whole. I doubt not that if the region studied, extending from Tarpaulin Cove on the south side of Naushon to Falmouth, a distance of twelve miles, were carefully examined, more than a thousand kettle-holes could be mapped.

Many of these depressions have water in them forming a small pond or lake. The depth of the ponds could only be estimated, except for No. 53 of table No. 1, which has considerable size, and is called "Mary's Lake." I learned from the owner of the land that its depth is eighteen feet. The map here given, shows with approximate correctness, the distribution of the kettle-holes, and also the direction of the longer axes. By a glance at the map it will be seen that the general trend of the longer axes is nearly that of the terminal moraine.

Some few kettle-holes were found with circular depressions and these were omitted, but all with the longer diameter transverse to the general trend were measured and recorded.

Over the hilly region to the northeast of Wood's Holl, many of the gulleys or ravines run northeast and southwest, about in line with the trend of the Elizabeth Island; the hills also have largely this direction. The small bays among the islands usually have their longest axis trending approximately northeast and southwest.

Some of these kettle-holes are upon a truly grand scale; as for example No. 61, which contains several smaller within the large depression, and is like an immense amphitheater with the hills rising upon every side of it. Its highest border is one hundred and fifty feet above the bottom and the outlet is forty feet above the small lake at its center; and on the south side, near its border, but upon still higher ground, bowlder No. 6, of table No. 2, stands projected against the southern sky like a huge sentinel as the observer views it from the bottom of this immense pit.

It occurred to me before entering upon this study, that possibly observations on the direction of the longer axis, the side upon which the highest border is found, position of the outlet, distribution, etc., might throw light on the origin of these kettle-holes. But there seems to be no uniformity in any of these characters except the first and second. After examining all the facts, I am led to conclude that the arrangement of this axis supports the theory that the depressions were made by ice. In many cases it appears as if a long, narrow block of ice, broken from the front of the glacier, had lodged against the material which was in front of it, and then had become covered up by other materials; finally on melting it left the long kettle-hole with a high southern border. A couple of these are found just at the edge of the village of Wood's Holl, while in many others the appearance suggests that the ice mass was covered by material from the northwest, and the result was a kettle-hole with a high steep northwest border. Many of the kettle-holes having either a high border on the southeast or northwest, or approximating these points, seem to sustain this view. In the

study of the geological characters of the eastern part of Connecticut, I have found numerous kettle-holes in the middle of wide level plains, of terrace origin, where it seemed that no known cause of the present, except stranded ice, could make them. It was my intention to have given further study to the kettle-holes of Naushon, in order to ascertain whether the kettle-holes are more numerous on the northern or the southern slope of the island. I could command time for only one day's work upon this island, and in it was assisted by Professor Edwin Linton, of Washington College, Penn.; and I did not carry the investigation far enough to decide with certainty upon the point. As to those upon Nonamesset, the mainland, and those examined on Naushon, the facts indicate with a good deal of certainty that they are much more numerous and generally larger upon the northern slope than upon the southern.

The observed facts pertaining to the kettle-holes are given in table No. 1; and those as to some large bowlders in table No. 2.

No. 1.

On the Mainland.

No.	Direction of long axis.	Length of long axis.*	Length of short axis.*	Height of outlet.	Highest border.	Position of highest border.	Depth of water.
1	N. 10° W.	12 rods.	6 rods.	10 ft.	25 ft.	N.E.	8 ft.
2	N. 40° E.	8	6	4	25	S.	5
3	N. 50° E.	7	5	5	24	E.	3
4	N. 40° W.	10	6	5	30	E.	5
5	N. 10° W.	6	3	5	21	E. by N.	--
6	N. 50° E.	40	25	45	75	N.E.	6
7	N. 20° W.	30	12	18	40	----	6
8	N. 20° E.	10	4	12	25	----	--
9	N. 15° E.	10	4	3	15	----	--
10	N. 20° E.	7	4	5	20	----	--
11	N. 25° E.	40	12	50	76	N.E.	--
12	N. 30° E.	15	8	25	50	N.E.	--
13	N. 5° E.	25	10	40	68	S.W.	--
14	N. 35° E.	12	10	7	25	S.E.	--
15	N. 60° E.	8	5	5	25	S. by E.	--
16	N. 5° E.	25	8	45	66	N.W. & S.E.	--
17	N.	20	10	25	60	S.W.	--
18	N. 40° E.	60	43	42	73	N.W.	--
19	N. 35° E.	35	7	15	30	N.N.W.	5
20	N. 20° E.	30	10	6	40	S.W.	--
21	N. 35° E.	30	12	25	95	S.S.E.	--
22	N. 10° W.	16	9	13	50	S.W.	--
23	N. 80° E.	50	40	25	--	----	swamp.
24	N. 10° E.	10	6	18	38	E.S.E.	3 ft.
			On the Island of Uncatina.				
25	N. 70° E.	25	10	8	18	N.W.	--
26	N. 60° E.	18	7	5	20	N.E.	--
27	N.	8	6	4	25	N.N.S.	--
28	N. 20° E.	16	12	12	22	N.	--
29	N. 28° E.	38	20	12	25	S.E.	--
30	N. 30° E.	16	12	7	17	S.	--
31	N. 30° E.	11	5	3	25	S.	--
32	N. 30° E.	7	6	5	23	W. by N.	--

* At the level of the outlet.

On the Island of Nonamesset.

No.	Direction of long axis.	Length of long axis.*	Length of short axis.*	Height of outlet.	Highest border.	Position of highest border.	Depth of water.
33	N. 25° E.	12 rods.	6 rods.	7 ft.	30 ft.	S.	4 ft.
34	N. 40° E.	10	5	5	35	N.	5
35	N. 20° W.	14	9	10	35	W.	--
36	N.	20	12	5	40	N.	5
37	N. 60° E.	12	7	8	28	N.W.	--
38	N. 40° E.	6	4	2	28	N.	--
39	N. 20° E.	6	4	5	20	E.	--
40	N. 55° E.	20	10	16	28	W. by S.	--
41	N. 40° E.	8	4	12	20	W.	--
42	N. 50° E.	7	4	10	25	S.S.W.	--
43	N. 25° E.	13	5	10	25	W. by S.	--
44	N. 20° E.	16	9	12	30	N.W.	--
45	N. 35° E.	8	5	5	25	S.E.	5
46	N. 50° E.	8	3	5	18	N.W.	--
47	N. 60° E.	18	8	7	20	E.	--
48	N. 70° E.	18	6	14	23	S.	--
49	N. 80°	18	3	8	50	S.	3
50	N. 30° E.	8	4	4	25	N. by E.	--
51	N. 10° E.	20	12	5	25	N.N.W.	--
52	N. 28° E.	60	25	15	30	N.	6

On the Island of Naushon.

53	N. 25° E.	60	40	18	50	N.E.	Mary's Lake. 18
54	N.	20	8	10	25	N.	swamp
55	N. 80° E.	20	8	5	35	----	--
56	N.	18	12	4	35	----	--
57	N. 20° E.	20	5	8	40	----	--
58	N. 30° E.	30	4	6	50	----	--
59	N.	6	4	5	25	----	--
60	N. 15° E.	40	6	20	45	W.	--
61	N. 40° E.	75	40	40	150	S.W.	5 ft.
62	N. 30° E.	80	10	25	100	S. by W.	5
63	N. 10° W.	10	5	12	55	S.W.	5

* At the level of the outlet.

No. 2.

Dimensions of Bowlders.

	Greatest length.	Greatest width.	Greatest height above surface of ground.	Locality, etc.
1	24 ft.	10 ft.	9 ft.	Center of Nonamesset.
2	24	10	4	Center of Nonamesset, and buried very deep in ground.
3	18	18	7	Center of Nonamesset, and buried very deep in ground.
4	10	11	6	Near Mary's Lake, very deep.
5	12	9	6	Near Mary's Lake, very deep.
6	12	10	5	Near Mary's Lake, very deep.
7	24	15	12	Near No. 61, slightly buried.
8	27	18	4	Near stratified deposit upon Naushon, and very deep.
9	27	15	16	Near stratified deposit upon Naushon, and on surface.

ART. XXXI.—*Examination of Mr. Alfred R. Wallace's Modification of the Physical Theory of Secular Changes of Climate;* by JAMES CROLL, LL.D., F.R.S.

[Continued from page 93.]

IN the examination of Mr. Wallace's main argument, I shall consider it, first, in relation to physical principles, and, secondly, in relation to geological and paleontological facts.

I. *Physics in relation to Mr. Wallace's Modification of the Theory.*

The grand modification, that during the height of the glacial epoch the snow and ice would not disappear when precession brought the winter solstice round to perihelion, I have already given in Mr. Wallace's own words. As the reasons which he assigns for this modification are very briefly stated by him, I may here give them also in his words.

After describing the state of Northeastern America and the North Atlantic, to which I have already alluded, he says:

"But when such was the state of the North Atlantic (and, however caused, such *must* have been its state during the height of the glacial epoch), can we suppose that the mere change from the distant sun in winter and near sun in summer, to the reverse, could bring about any important alteration—*the physical and geographical causes of glaciation remaining unchanged?* For, certainly, the less powerful sun of summer, even though lasting somewhat longer, could not do more than the much more powerful sun did during the phase of summer in *perihelion*, while during the less severe winters the sun would have far less power than when it was equally near and at a very much greater altitude in summer. It seems to me, therefore, quite certain that whenever *extreme* glaciation has been brought about by high eccentricity combined with favorable geographical and physical causes (and without this combination it is doubtful whether *extreme* glaciation would ever occur), then the ice-sheet will *not* be removed during the alternate phases of precession, so long as these geographical and physical causes remain unaltered. It is true that the warm and cold oceanic currents, which are the most important agents in increasing or diminishing glaciation, depend for their strength and efficiency upon the comparative extents of the northern and southern ice-sheets; but these ice-sheets cannot, I believe, increase or diminish to any important extent unless some geographical or physical change first occurs."—p. 150.

Again,—"It is quite evident that during the height of the glacial epoch there was a combination of causes at work which led to a large portion of Northwestern Europe and Eastern America being buried in ice to a greater extent even than Greenland. Among

these causes we must reckon a diminution of the force of the Gulf-Stream, or its being diverted from the northwestern coasts of Europe; and what we have to consider is, whether the alteration from a long cold winter and short hot summer, to a short mild winter and long cool summer would greatly affect the amount of ice *if the ocean-currents remained the same.* The force of these currents are, it is true, by our hypothesis modified by the increase or diminution of the ice in the two hemispheres alternately, and they then react upon climate; but they cannot be thus changed till after the ice-accumulation has been considerably affected by other causes."—p. 148.

There are some further reasons assigned, which will be considered as we proceed.

From what has already been shown, it will be seen that the causes which led to the Glacial epoch may be classed under three distinct groups:—(1) the astronomical, (2) the physical, and (3) the geographical. This threefold division is distinctly recognized by Mr. Wallace in the above quotations, as well as in all his reasoning on the subject of geological climate.

In the astronomical group the main elements are the two following:—1st. A high state of eccentricity producing, on the hemisphere whose winter solstice happens to be in aphelion, a long and cold winter with a short and hot summer, and on the other hemisphere, whose winter solstice, of course, at the time is in perihelion, a short and mild winter with a long and cool summer. 2d. Precession, transferring these conditions from the one hemisphere to the other alternately every 10,000 or 12,000 years. The physical elements are, of course, the influence of snow and ice, ocean currents, aqueous vapor, clouds, fogs, and a host of other things which have already been discussed at length;* while the geographical consist of the particular distribution of land and water, elevations or depressions in the sea-bottom, contour of the sea-coast, and other geographical conditions influencing the flow of ocean-currents.

It is to the influence of physical agencies, however, that the Glacial epoch is more directly due. The main function of the astronomical agents is to set and keep the physical agencies in operation, and also to *determine* the character of their operations. For example, the position of the winter solstice in relation to the aphelion or to the perihelion, during a high state of eccentricity, determines whether the physical agencies will produce on a given hemisphere a glacial or a warm condition of climate; while precession determines which of the two hemispheres shall be the glaciated and which the warm. In one respect we may say that the astronomical causes produce glaciation by means of the physical agencies.

* 'Climate and Time,' chap. iv: American Journal of Science, Oct., 1883; Phil. Mag. Oct., 1883.

The geographical conditions, however, cannot properly be considered to be causes in the sense in which the astronomical and physical are. They are more properly *conditions* to the production of a glacial epoch than *causes*. They cannot be said to *act* in the production of glaciation. They are rather permanent and passive conditions enabling the active causes to produce their required effects. Had the Glacial epoch resulted from elevation of the land, as some geologists suppose, then this *elevation* might properly be said to have been the cause of the Glacial epoch; but the Glacial epoch was produced by no such means, nor by any *change* in the physical geography of the globe. A certain geographical condition of things was, of course, requisite in order to the effective operation of the astronomical and physical causes. This condition existed at the time of the glacial epoch; and it is only in this sense that that epoch can be referred to any thing geographical.

It is true that a cause, as Sir William Hamilton states, may be defined as "all that without which the effect would not happen;" but this is far too general an expression of cause for practical purposes. We therefore fix on the particular antecedent or antecedents, through the activity of which the event is mainly brought about, and term them the causes of the event, and the others the necessary conditions.

I cannot help thinking that the way in which geographical conditions are spoken of as causes of the Glacial epoch has tended to confusion.

During the Glacial epoch there were frequent submergences and elevations of the land, or rather oscillations of sea-level, and these, it is true, would produce a change in the relative extent of sea and land. But whether we suppose it to have been the sea which rose and fell in relation to the land, or the land in relation to the sea, it equally follows that the geographical change resulting therefrom could not possibly have been a cause of the glacial epoch. It is now a well-established fact that submergence accompanied glaciation; the glaciation may have been that which led to the submergence; but it could not possibly have been the submergence which led to the glaciation. An elevation of the land would have favored glaciation, but submergence would not. Its tendency would rather be in the opposite direction. It is now also established, that during the continental period, or period of elevation, the climate was warm and equable; for it was then, as has been remarked, that this country was invaded by tropical and subtropical animals. Now it is equally plain that the elevation could not have been the cause of the heat. Elevation of the land might produce cold, but it could not have been a cause of the heat. It follows therefore that the geographical change

resulting from submergence or elevation of the land cannot be regarded as a cause of the glacial epoch; for its effect on climate, if it had any, was in opposition to that of the astronomical and physical agencies. It would prove a hindrance not a help.

Referring now to Mr. Wallace's argument. When glacial conditions in the North Atlantic attained their maximum development, "Can we suppose," he asks, "that the mere change from the distant sun in winter, and near sun in summer to the reverse, could bring about any important alteration—the physical and geographical causes of glaciation remaining unchanged?" Here, to begin with, we have an impossible state of things assumed. It is assumed in this question that it is possible for the winter solstice to pass from aphelion to perihelion, and the *physical* causes to remain unchanged. It is assumed as possible that the astronomical conditions might be reversed without a reversal of the physical.

When the winter solstice is in aphelion it sets in operation many physical causes, the tendency of which is to produce an accumulation of snow and ice; but when the solstice-point moves round to the perihelion, the tendency of these causes is reversed, and they then undo what they had previously done—melt the snow and ice which they had just produced. Now, what Mr. Wallace asks is this: When, owing to the winter solstice being in aphelion during a high state of eccentricity, a glacial condition of things is produced, will the fact of the solstice-point being moved round to perihelion remove the glacial condition, if *the physical causes remain unchanged in their mode of operation?* My reply is, it certainly would not. Here it is assumed that the physical causes are working in opposition to the astronomical; that when the solstice is in perihelion the action of the physical causes, instead of being reversed, as it should be according to theory, still continues to produce and maintain a glacial state of things, the same as it did when the solstice-point was in aphelion; and he asks, will the astronomical causes in this struggle manage to overpower the physical and produce a melting of the ice? I unhesitatingly reply, no; for the physical causes are far more powerful than the astronomical. The astronomical causes, as we have seen, are perfectly unable to produce a glacial state of things without the *aid* of the physical. How, then, could we expect that they could remove this glacial state if the physical causes were actually working against them.

In thus setting the physical causes against the astronomical, Mr. Wallace is basing his argument for the non-disappearance of the snow and ice on a state of things which cannot possibly under the circumstances exist. His question, to have consist-

ency, should be this:—When glacial conditions were at their height, &c., "can we suppose that the mere change from the distant sun in winter and the near sun in summer, to the reverse, could bring about any important alteration—the *geographical* causes of glaciation remaining unchanged?" If the question is put thus, and it is the only form in which it can be put to be consistent with the theory which Mr. Wallace himself advocates, then my reply is, that the change from the distant sun in winter and near sun in summer to the near sun in winter and distant sun in summer, aided by the change in the physical causes which this would necessarily bring about, would certainly be sufficient to cause the snow and ice to disappear without any change in the geographical condition of things. The combined influence of the astronomical and physical causes, when the winter solstice is in perihelion, is perfectly sufficient to undo all that they had previously done when the solstice was in aphelion. When the action of the causes is reversed, the effects will be reversed.

Had the Glacial epoch been produced by geographical causes, then it is probable that the ice would not have disappeared till these causes were changed. Had the ice, for example, been simply due to an elevation of the land, as some have argued, then it would not likely have disappeared till the land became lowered. But it was the result of no such cause. It was due, not to an elevation of the land, but to a number of physical causes, brought into operation by a high state of eccentricity. This Mr. Wallace fully admits and maintains. A certain geographical state of things was, of course, necessary to enable the astronomical and physical causes to produce the required effect; and this was really all that geographical conditions had to do in the matter. Let this be observed, however, that the *same geographical condition of things* which favors the accumulation of ice when the winter solstice is in aphelion, favors its disappearance when the solstice is in perihelion. This is obvious, because the same combination of physical agencies which makes the hemisphere in aphelion cold, makes the one in perihelion warm. The heating of the one is, to a large extent, the result of the cooling of the other. It is the *transference* of heat by ocean-currents from the hemisphere in aphelion to the one in perihelion which is a main reason why the former is cold and the latter warm. Hence a change in geographical conditions is unnecessary for the disappearance of the ice on the hemisphere with the perihelion winter, whether that hemisphere be the northern or the southern.

The tendency of the combined influence of all the causes—astronomical, physical, and geographical—is to cool the one hemisphere and to warm the other, to accumulate the ice on the

one and remove it from the other. Consequently the same total combination of causes which will produce an accumulation of ice on either hemisphere when the winter solstice is in aphelion will produce a melting of that ice when the solstice moves round the perihelion.

Another impossible condition assumed.— "What we have to consider," says Mr. Wallace, "is whether the alteration from a long cold winter and short hot summer, to a short mild winter and long cool summer, would greatly affect the amount of ice *if the ocean-currents remained the same.*" Here, again, we have an impossible state of things assumed. It is assumed that, notwithstanding the change from an aphelion to a perihelion winter, the ocean-currents would still remain the same. And it is asked, would the astronomical causes in this case remove the glaciation. I would be disposd to say that they would not.

"The force of these currents," he adds, "are, it is true, by our hypothesis modified by the increase or diminution of the ice in the two hemispheres alternately (they depend for their strength and efficiency upon the comparative extent of the northern and southern ice-sheets), and they then react upon climate; but they cannot be thus changed till after the ice-accumulation has been considerably affected by other causes."

What, then, are the other causes which affect the ice-accumulation and thus lead to a change in the ocean currents? "These ice sheets cannot, I believe," says Mr. Wallace, "increase or diminish to any important extent unless some *geographical* or *physical* change first occurs." The first thing required to affect the ice-accumulation is thus a geographical or a physical change. But we have just seen that the character of the physical causes depends upon the astronomical. A change from a long cold winter and short hot summer to a short mild winter and long cool summer would reverse the operations of the physical causes and lead to a melting of the ice. The physical causes therefore offer no barrier. What more do we still require? This we have in the following foot-note at page 150 :— "The ocean-currents are mainly due to the difference of temperature of the polar and equatorial areas combined with the peculiar form and position of the continents, and some one or more of these factors must be altered *before* the ocean-currents towards the North Pole can be increased."

One of these factors—change in the form and position of the continents—may be left out of consideration for we have no evidence of any such change during the Glacial epoch, except one which, as has been already proved, could have had no effect. We must therefore look to a change in "the difference of temperature of the polar and equatorial areas" for any increase in

the currents towards the North Pole. And in order to bring about this change, "the only available factor," Mr. Wallace states, "is the antarctic ice; if this were largely increased, the northward-flowing currents might be so increased as to melt some of the arctic ice. But without some geographical change the antarctic ice could not materially diminish during its winter *perihelion*, nor increase to any important extent during the opposite phase. We therefore seem to have no available agency by which to get rid of the ice over a glaciated country, so long as the *geographical conditions* remained unchanged and the eccentricity continued high."

According to Mr. Wallace, the *only* available factor to produce a difference of temperature between the south-polar area and the equator, so as to increase the north-flowing currents and thus melt the arctic ice, would be an increase of the antarctic ice; but this he considers impossible without some *geographical change*. Without such a change, the antarctic ice, he maintains, would neither be increased nor diminished. Hence it follows that without this change there is, according to Mr. Wallace's theory, no possibility of getting quit of our northern ice during interglacial periods.

This sweeping conclusion seems to be based on two assumptions, both of which appear to me to be erroneous. *First*, that the "only" factor available is the antarctic ice: and, *secondly*, that the antarctic ice can neither be increased nor diminished without some geographical change.

A Geographical change not necessary in order to remove the Antarctic Ice.—In reference to the first, that the antarctic ice is the "only" available factor, I shall presently show that there are other causes affecting the northward-flowing currents as powerfully as the antarctic ice. As to the second, that the antarctic ice can neither be increased nor diminished materially without some geographical change, this is an assumption based, no doubt, on the opinion which he holds that the antarctic ice is due to the elevated nature of that continent. Of course if this opinion be correct, then, without a lowering of the land, the ice can never disappear or be greatly changed in amount by astronomical or physical causes. But from what has already been stated in a former article* in reference to the condition of the antarctic continent, I think it is likely that it consists of low dismembered land or of groups of flat islands little elevated above sea-level, but all fused together by one continuous sheet of ice. In fact, it seems highly probable that a very large portion of the ice rests on a surface which is under the sea-level.

* "The Ice of Greenland and the Antarctic Continent not due to Elevation of the Land," Phil. Mag. November, 1883.

If this be the case, the antarctic ice is just in the condition admitting of its being easily modified by warm currents from equatorial regions. In fact at the very present day, as Dr. Neumayer has shown, the slight southward deflections of the warm westerly drift-current caused by the projecting land-masses of Australia, Africa, and South America, cut notches in the ice-cap. When the southern winter solstice was in perihelion during the glacial epoch, it is probable the greater part of the ice then disappeared.

In fact this is a result which would be even still more likely to occur were the views held by Sir Joseph Dalton Hooker and some others as to the nature of the antarctic ice proved to be correct. Sir Joseph thinks that much of the Antarctic ice-sheet, thousands of feet in thickness as it is, was formed by the successive accumulations of snow year by year on pack-ice. The snow fall in the Antarctic regions he believes to be enormous during both summer and winter; and as but a very small portion of it melts, the accumulated snow is perfectly sufficient to form such a sheet. He does not consider that there is land enough in the south-polar area to supply the astounding number and gigantic size of the icebergs that infest the ocean between lat. 50° and 70°. If this theory of Sir Joseph's be correct, and that immense masses of the ice be really afloat, we can easily understand how the whole might, during a southern interglacial period, be broken up, dispersed, and melted by an inflow of equatorial water.

I think, however, that the whole of that enormous sheet from which the icebergs are derived must be resting on the ground, although it is very likely, as has been shown on a former occasion,* that a very large portion of it may be on the sea-bottom. The weight of evidence seems to be in favor of the opinion that there is much to favor the assumption that there are large areas within the antarctic circle consisting of low flat groups of islands separated by broad and shallow seas which have all become filled with solid ice. It is quite possible that the ice filling these seas may have originated in pack-ice, which ultimately became converted into a solid and continuous sheet by long ages of successive snowfalls. As layer after layer, converted into ice, was being heaped upon it year by year, the mass would gradually sink till it rested on the sea-bottom.†

* Phil. Mag., November, 1883, p. 357.

† In this opinion I am glad to find that Sir Joseph to a certain extent concurs, for in a letter to me on the subject he says:—"I cannot doubt but that the icebergs have originated from the ice of the great southern barrier; and what I suspect is that much of this barrier-ice originated in pack-ice over very shallow bays, increased by successive snowfalls. The quantity of snow that falls in summer is enormous south of latitude 50°–60.° Certainly it fell on half the days of each summer month during the three seasons we spent in those seas, and I think

After this it would assume all the characteristics of continental ice. In fact we have a condition of things exactly similar in the North Sea during the height of the glacial epoch (see 'Climate and Time,' p. 449).

If such be the condition of the antarctic ice, we can readily understand how it might all soon disappear under the influence which would be brought to bear upon it were the eccentricity high and the southern winter solstice in perihelion. The warm and equable conditions of climate which would then prevail, and the enormous quantity of intertropical water carried into the Southern Ocean, would soon produce a melting of the ice. Layer after layer would disappear off the surface, and as soon as the weight of the sheet became less than that of the water which it had displaced, the sheet would float. After this it would no doubt shortly break up and become dispersed.

Other causes than Antarctic Ice affecting the Northward-flowing Currents.—If we consider the effect which the present amount of eccentricity, small as it is, has on the climatic condition of some parts of the southern hemisphere, we shall readily understand how, during the glacial epoch, the warm water of this hemisphere may have been impelled northward, even independently of the influence of the antarctic ice. In order to show the present effect of eccentricity on climate I cannot do better than quote Mr. Wallace's own words on the subject. Referring to its effects on south temperate America, he says:

"Those persons, who still doubt the effect of winter in *aphelion* with a high degree of eccentricity in producing glaciation, should consider how the condition of south temperate America at the present day is explicable if they reject this agency. The line of perpetual snow in the southern Andes is so low as 6000 feet in the same latitude as the Pyrenees; in the latitude of the Swiss Alps, mountains only 6200 feet high produce immense glaciers which descend to the sea-level; while in the latitude of Cumberland, mountains only from 3000 to 4000 feet high have every valley filled with streams of ice descending to the sea-coast and giving off abundance of huge icebergs. Here we have exactly the condition of things to which England and Western Europe were subjected during the latter portion of the glacial epoch, when every valley in Wales, Cumberland, and Scotland had its glacier; and to what can this state of things be imputed, if not to the fact that

in one month snow fell *every day*. There is no summer melting of snow and ice in the Antarctic as there is in the Arctic regions. It is the only region known to me where there is perpetual snow on land at sea-level."

Now if the snow which falls in the Antarctic regions at the sea-level does not all melt, but some of it remains year by year, then permanent ice formed at the sea-level, whether it be on frozen pack or on the ground, must be a necessary consequence. If this be so, it cannot be true, as Mr. Wallace affirms, that there is no permanent ice formed but on high land.

there is now a moderate amount of eccentricity and the winter of the southern hemisphere is in *aphelion?* The mere geographical position of the southern extremity of America does not seem especially favorable to the production of such a state of glaciation. The land narrows from the tropics southward, and terminates altogether in about the latitude of Edinburgh; the mountains are of moderate height; while during summer the sun is three millions of miles nearer, and the heat received from it is equivalent to a rise of 20° F. as compared with the same season in the northern hemisphere."—P. 142.

In a similar glacial condition are the islands of South Georgia, South Shetland, Graham Land, Enderby Land, Sandwich Land. There can be little doubt that the present extension of ice in the antarctic regions is to a considerable extent due also to the influence of eccentricity.

Let us now glance for a moment at the influence which this state of things has at present on northward-flowing currents. One result is that the southeast trades are stronger than the northeast, and as a consequence blow over on the northern hemisphere ten or fifteen degrees beyond the equator. This has the effect, as has been shown ('Climate and Time,' chapters v and xiii, and other places), of impelling the warm surface-water of the southern intertropical regions over on the northern hemisphere. It is possible that the greater strength of the south-east trades may to some extent be due to the preponderance of ocean on the southern hemisphere; but there can be little doubt that it is mainly the effect of eccentricity.

The result of this transference of water from the southern to the northern hemisphere is that the intertropical waters of the northern hemisphere are between three and four degrees warmer than those of the southern. Another result which follows, as has also been shown, is that the great equatorial currents are made to lie at some distance to the north of the equator; hence when they are impelled against the American and the Asiatic continents, and become deflected northwards and southwards, the larger portion of the water goes to the north, and thus raises the temperature of the northern hemisphere. Now if all this results as a consequence from the present small amount of eccentricity, how much greater must have been the effect during the glacial epoch, when the eccentricity was more than three times its present value and the southern winter also, as now, in aphelion! All those effects which we have just been considering would then have been magnified far more than threefold.

Climatic conditions of the two Hemispheres the reverse 10,000 *or* 12,000 *years ago: Argument from.*—Ten or twelve thousand years ago, when our northern winter solstice was last in aphe-

lion, the climatic conditions were in all probability the reverse of what they are at present. There appears to be pretty good geological evidence that such was the case. This, under the present small amount of eccentricity, shows not only to what an extent climate is affected by eccentricity, but also (and with this we are at present more particularly concerned) that its tendency is to cool the one hemisphere and warm the other, to accumulate the snow and ice on the one and melt them on the other. And this result, to a large extent, is doubtless brought about by its influence on ocean-currents.

There are good reasons for concluding, as Prof. J. Geikie has fully shown,* that at a very recent date (during the time of the formation of the 40-feet raised beach and the deposition of the Carse-clays) the climate was much colder than it is at present. The seas surrounding our Island appear to have had a lower temperature than they have at present; and our Highland valleys seem to have been occupied by local glaciers.†

The Carse-clays of Scotland are best developed in the valleys of the Tay, the Earn, and the Forth. These deposits consist of finely laminated clays and silt. "Now and again," says Prof. J. Geikie, "the deposits consist of tough tenacious brick-clay, which does not differ in appearance from similar brick-clays of glacial age." The clay is usually free from stones, but occasionally blocks of six inches or a foot in diameter are found in it; and Prof. J. Geikie mentions having seen one four feet in thickness. Stones of this size in a fine laminated clay evidently indicate the presence of floating ice. But, as Prof. Geikie remarks, "it is rather the general character of the clays themselves than the presence of erratics which indicates colder climatic conditions. The fine tenacious brick-clays are not like the dark sludge and silt which now gather upon the estuarine bed of the Tay, but resemble and in some cases are identical in character with the laminated clays of true glacial age with arctic shells." These Carse-clays, as he further remarks, appear in a large measure to be made up of the fine "flour of rock" derived from the grinding action of glaciers which then occupied the Highland valleys, and from which muddy waters escaped in large quantities in summer owing to the melting of the snow and ice. In short, these Carse-clays appear to coincide with the most recent period of local glaciers.

During that period some of the glaciers, as Professor J. Geikie has shown, appear to have even reached the sea-level.

* 'Prehistoric Europe.'

† In a paper "On the Obliquity of the Ecliptic," read before the Geological Society of Glasgow in 1867. I concluded that at the time of the deposition of the Carse-clays the mean winter temperature was probably 10° or 15° lower than at present, and the Gulf-stream considerably reduced. See also 'Climate and Time,' pp. 403–410.

For example, at the mouth of Glen Brora, in Sutherland, there is a well-marked moraine with large blocks resting upon, and apparently of the same age as, the deposits of the raised beach.* Mr. Robert Chambers also observed moraine matter resting upon the 30-feet beach at the opening of Glen Iorsa, in Arran. In many of the Highland sea-lochs, says Professor J. Geikie, glaciers appear to have come down to the sea and calved their icebergs there. This, he thinks, is probably the reason why the 40–50-feet beach is not often well seen at the heads of such sea-lochs. The glaciers seem in many cases to have flowed on for some distance into the sea, and thus prevented the formation of a beach and cliff-line.

The greater magnitude and torrential character of the rivers of that period were no doubt due to the melting during summer of great masses of snow and ice. The presence of the large Greenland whale, found frequently in the Carse deposits, would seem to indicate a somewhat colder sea than now surrounds our island. A decrease of temperature of the sea is what would necessarily occur from a slight diminution in the volume of the Gulf-stream, arising from the greater deflection of equatorial water into the southern hemisphere.

Another circumstance deserves notice here, as it seems to indicate that the climatic conditions of the two hemispheres were at the period of the Carse clays the reverse of what they are at present. During that period the sea stood higher in relation to the land than it does at the present time. To this circumstance alone no great importance can be attached; but when we consider in addition that submergence has almost invariably accompanied glaciation, we may regard it as highly probable that the submergence at the period in question was the result of a greater amount of ice on the northern hemisphere and a less amount on the southern, than now. This probability is further increased by the fact that during the growth of the ancient Forest, which immediately underlies the Carse-clays, and indicates a condition of climate even more warm and equable than the present,† the sea stood not only higher in relation to the land than it did during the time of the deposition of the Carse-clays, but somewhat higher than it does at present. The buried Forest doubtless belongs to the period 10,000 or 12,000 years prior to that of the Carse-clays,‡ when the winter solstice was in perihelion; and at this time, owing to a somewhat greater amount of eccentricity than at

* 'Prehistoric Europe,' p. 411.

† Those who doubt the equable and warmer character of the climate of the submarine Forest-bed period should study the mass of evidence on this point given in 'Prehistoric Europe.'

‡ For the probable dates of the Carse-clays and the submarine Forest-beds see Appendix.

present, the quantity of ice on the southern hemisphere might be expected to be greater and that on the northern less than now.

Thus when the northern winters were last in aphelion there was a *rise* of sea-level, resulting doubtless from a preponderance of ice on the northern hemisphere; but when the buried Forest flourished 10,000 or 12,000 years prior, the winters were in perihelion, and there was a *fall* of sea-level, due in all likelihood to the preponderance of ice on the southern hemisphere. But this is not all: the strata which underlie the buried Forest bear witness to another *rise* of sea-level.

These changes of climatic conditions and oscillations of sea-level, which took place during the latter part of the Postglacial period, are just what should have taken place on the supposition that they were the result of those astronomical and physical agents which we have been considering. Thus, immediately preceding the Present period we have that of the 25- and 40-feet* raised beaches and the Carse deposits, which indicate that the climate was then more severe and the sea somewhat colder and standing at a higher level than at present. Now during this Recent period our northern winter solstice was in aphelion, and the condition of things is exactly what, according to theory, we ought to expect.

Preceding the period of the Carse-clays comes that of the buried Forest, when the climate was even more genial and equable than at the present day, the Gulf-stream larger and the sea at a lower level than now. Now during this period the winter solstice was in perihelion and the eccentricity somewhat greater than at present; and here again we have exactly that condition of things which, according to theory, we ought to expect. It would be very singular indeed were there no physical connection between these conditions and the causes to which I have been attributing them. It would certainly be singular were all these coincidences purely accidental. These changes have all been so recent, geologically speaking, and so general and widespread in their character, that they cannot reasonably be attributed to any known geographical changes. If we admit, then, that they were the result of those astronomical and physical agents to which I have referred them, we must also admit that those agents were as efficient in producing a warm and equable climate as in producing a cold and severe one. We must further admit that, with a very small amount of eccentricity, widely marked differences of cli-

* At one time I thought ('Climate and Time,' p. 409) that the 40-feet beach might belong to a period 50,000 years prior to the Carse-clays; but I am now satisfied that the two beaches both belong to the period of the Carse-clays, as Professor J. Geikie has shown.

matic conditions are brought about on the two hemispheres; that, when the winters are in perihelion, the melting of the snow and ice and the increase of the Gulf-stream and other northward-flowing currents are as necessary a result as were the formation of the snow and ice and the decrease of the Gulf-stream and those currents when the winters were in aphelion. And if this holds true in reference to recent and postglacial times, when the eccentricity was small, it must, for reasons which will presently be stated, hold true in a higher degree in reference to the glacial epoch, when the eccentricity was more than three times its present value.

The Mutual Reaction of the Physical Agents in relation to the Melting of the Ice.—When the winter solstice is in aphelion it sets in operation, according to theory, as has been shown, a host of physical causes, the tendency of which is to produce an accumulation of snow and ice; but when the solstice-point moves round to perihelion the tendency of these causes is reversed, and they then undo what they had previously done—they melt the snow and ice which they had just produced. The action of the causes being reversed, the effects are reversed. But it must be observed that the greater the amount of the eccentricity, the greater will be the effect resulting from the combination of these physical agents, whether that effect be the production of snow and ice on the cold hemisphere, or the melting of them on the warm—whether it be their production when the winter solstice of a hemisphere is in aphelion, or their melting when that solstice is in perihelion.

We have, however, to take into account not merely the action of the physical agents, but their mutual reactions on one another. The effect of this mutual reaction is very striking. Not only do the physical agents, in their actions, all lead to one result, viz: an accumulation of snow and ice when the winters are in aphelion, but their efficiency in bringing about this result is actually strengthened by their mutual reactions on one another. To illustrate this effect I quote the following from a former article:

'To begin with, we have a high state of eccentricity. This leads to long and cold winters. The cold leads to snow, and although heat is given out in the formation of the snow, yet the final result is that the snow intensifies the cold; it cools the air and leads to still more snow. The cold and snow bring a third agent into play—*fogs*, which act still in the same direction. The fogs intercept the sun's rays, this interception of the rays diminishes the melting-power of the sun, and so increases the accumulation. As the snow and ice continue to accumulate, more and more of the rays are cut off; and on the other hand, as the rays continue to be cut off, the *rate* of accumula-

tion increases, because the quantity of snow and ice melted becomes thus annually less and less. In addition, the loss of the rays cut off by the fogs lowers the temperature of the air and leads to more snow being formed, while again the snow thus formed chills the air still more and increases the fogs. Again, during the winters of a glacial epoch, the earth would be radiating its heat into space. Had this loss of heat simply lowered the temperature, the lowering of the temperature would have tended to diminish the rate of loss; but the result is the formation of snow rather than the lowering of the temperature.

'Further, as snow and ice accumulate on the one hemisphere they diminish on the other. This increases the strength of the trade-winds on the cold hemisphere and weakens those on the warm. The effect of this is to impel the warm water of the tropics more to the warm hemisphere than to the cold. Supposing the northern hemisphere to be the cold one, then, as the snow and ice begin gradually to accumulate, the ocean-currents of that hemisphere, more particularly the Gulf-stream, begin to decrease in volume, while those on the southern or warm hemisphere begin *pari passu* to increase. This withdrawal of heat from the northern hemisphere favors the accumulation of snow and ice, and as the snow and ice accumulate the ocean-currents decrease. On the other hand, as the ocean-currents diminish, the snow and ice still more accumulate. Thus the two effects, in so far as the accumulation of snow and ice is concerned, mutually strengthen each other.'

With all this Mr. Wallace seems fully to agree; for at pp. 137–140 ('Island Life') he gives a very clear statement of the effect of these mutual reactions in the production of glaciation, and says that were it not for them it is probable the astronomical and other causes would not in our latitudes have been sufficient to produce glaciation. In short, he concludes that these reactions "produce a maximum of effect which, without their aid, would be altogether unattainable." Mr. Wallace thus does full justice to these mutual reactions in so far as the production of glaciation is concerned; but I am convinced that he must have underestimated their importance as regards the removal of the glaciation. He, however, recognizes the fact that these mutual reactions produce an opposite effect on the warm atmosphere whose winters are in perihelion. "These agencies," he says, "are at the same time acting in a reverse way in the southern hemisphere, diminishing the supply of the moisture carried by the anti-trades, and increasing the temperature by means of more powerful southward ocean-currents; and all this again reacts on the northern hemisphere, increasing yet further the supply of moisture by the more powerful south-

westerly winds, while still further lowering the temperature by the southward diversion of the Gulf-stream."

Now if, during the glaciation of the northern hemisphere, these mutual reactions produce the opposite effect on the southern hemisphere, it is evident that they must produce this same opposite effect on the northern hemisphere when its winter solstice is in perihelion. Their effect then would be to increase the temperature and melt the ice. When the winter solstice is moving towards the aphelion, the physical agents begin to act and also to react on one another, and this action and reaction goes on increasing in intensity till the solstice-point reaches the aphelion; but an exactly similar thing is going on in the other hemisphere, only the effects are the reverse. While the actions and reactions leading to an accumulation of ice are increasing in intensity, we shall suppose, on the northern hemisphere, the same increase is taking place on the southern hemisphere; but the result is a melting, not an accumulation of the ice. The same process is undoing on the southern hemisphere what it is doing on the northern. Similarly, of course, when the northern winter solstice begins to move towards the perihelion, the mutual reactions of these physical causes will be reversed and will go on with increasing intensity till the perihelion is reached, melting the very ice which they had previously produced.

We have already seen that the greater the extent of the eccentricity, the greater is the effect resulting from the *actions* of the physical causes, whether this effect be the production of ice on the cold hemisphere, or its removal from the warm. It is evident that the same thing must necessarily hold true in regard to the mutual *reactions* of the physical causes. Consequently if the mutual actions and reactions of the physical causes, brought into operation during a high state of eccentricity, led at the glacial epoch to the great accumulation of ice when the winters were in aphelion, they must have led to an equally great melting and dispersal of that ice when precession brought the winters round to perihelion. These causes would be as efficient in the removal of the ice as they were in its production. In so far as the physical and astronomical causes were concerned, the greater the amount of ice formed during the cold periods the greater would be the amount melted during the warm interglacial periods.

Another reason assigned why the ice does not melt.—Mr. Wallace assigns the following as an additional reason why the ice does not disappear during the interglacial periods when the eccentricity is high:

"When a country is largely covered with ice, we may look upon it as possessing the accumulated or stored-up cold of a long series of preceding winters; and however much heat is poured upon it, its temperature cannot be raised above the freezing-point till that store of cold is got rid of—that is, till the ice is all melted. But the ice itself, when extensive, tends to its own preservation, even under the influence of heat; for the chilled atmosphere becomes filled with fog, and this keeps off the sun-heat, and then snow falls even during summer, and the stored-up cold does not diminish during the year. When, however, only a small portion of the surface is covered with ice, the exposed earth becomes heated by the hot sun, this warms the air, and the warm air melts the adjacent ice. It follows that, towards the equatorial limits of a glaciated country, alternations of climate may occur during a period of high eccentricity, while nearer the pole, where the whole country is completely ice-clad, no amelioration may take place." —P. 154.

For the past nineteen years I have been maintaining that, when a country is covered with ice, it becomes a permanent source of cold; and however much heat may be received from the sun, the temperature of the surface can never be raised above the freezing-point while the ice remains; and, again, that such an ice covering tends to its own preservation, because it chills the air and increases the snow fall. In short I have all along maintained this to have been one of the chief causes which led to the country being so deeply covered with ice. In fact, had it not been for some such conservative power in the ice, a glacial epoch resulting from the causes which I have been advocating would not have been possible. This conservative tendency certainly renders it more difficult for the physical agencies to get rid of the ice during interglacial periods; but we evidently have no grounds for assuming that it will defy their melting-powers.

I shall next consider Geological and Paleontological facts in relation to Mr. Wallace's modification.

ART. XXXII.—*A Contribution to the Geology of Rhode Island;* by T. NELSON DALE.

[Continued from page 228.]

Dutch Island.—The mica schist and conglomerate of 115, Beaver Head, recur here at 128; the conglomerate, measuring two feet, reappears at 129; the mica schist is garnetiferous, plicated and folded. These plications characterize the whole east side of the island. A remarkably fine section of them is exposed at a small recess between the upper and lower docks, 130, where, in a cliff fifteen feet high, the schists are folded two or three times, the last fold being directly over the first, and the strike N.N.E. At one place a fold has ruptured and a fault ensued. Portable and most instructive specimens of plicated schist can here be obtained. One such, measuring now $5\frac{1}{2}'' \times 10'' \times \frac{3}{4}$ inches, when each bend is measured, gives $8\frac{1}{2}'' \times 10'' \times \frac{3}{4}$ inches for its original size. It has three folds lengthwise, each forming an angle of 60°, but two of the folds die out toward one end where it has the shape of a flat-bottomed trough. Between 128 and 129, and north of the upper wharf, the edges of about ten feet of mica schists are exposed on the beach, dipping 60° N.N.W., their upper portions having been there eroded, but in the adjoining bank they are seen to fold over upon themselves, dipping 25° S.S.W. At 131, south of the lower wharf, ten feet of micaceous conglomerate and grit dip 60° E.S.E., above and below which are mica schists which continue to the light-house, there highly inclined or vertical. Near 132, at the north end, the mica schist dips 50° N.W. to vertical. Between 132 and 133 the dip is first southeastward, then vertical, then slightly N.W., the strike being N.E. to N.N.E. The rocks are garnetiferous mica schist with some small layers of micaceous, garnetiferous grit and conglomerate. Small pebbles of opalescent quartz occur in the grits. The pebbles of the conglomerate are uniformly flat and either quartzyte or mica schist. The mica schist is very different from that of "Paradise," being much more micaceous and brilliant, always garnetiferous and sometimes minutely crumpled in one or even in two directions. Among these layers occur several small layers of dark argillyte containing garnets and radiated crystal of hornblende or chlorite, which rock sometimes passes into a garnetiferous hornblende or chlorite schist. Quartz veins, either milky or hyaline, abound and contain some crystals of feldspar. Between 133 and 134 are no outcrops. At 134, two beds of highly carbonaceous and graphitic schist, separated by a layer of light colored

mica schist and conglomerate, dip 45° E.S.E. It is quite possible that these pass horizontally into the regular graphitic coal. In proximity to them at 134 is a layer of carbonaceous, garnetiferous argillyte. At 135 the mica schist dips 70° E.S.E.

Packard's Rocks, Bonnet Point, Narraganset Pier.—At 136, on the mainland, West Passage, alternating dark and light mica schists, without garnets, dip 35°–40° E., the difference between them lying in the relative proportion of black mica. These schists extend north to Plum Beach and N.W. to 137 and beyond, and recur south at Packard's Rocks with the same dip. There the light colored layers are a highly metamorphosed grit with some large quartz pebbles. At 138, one and one-quarter mile south, these rocks dip 25°–35° E.S.E., then 25°–30° W.S.W., and are crossed by a granite vein. North of the "South Ferry" the dip is E.S.E., and a vein eight feet thick of cream-colored granite crosses E.S.E.–W.N.W. about vertically. The mica schists recur just south of the ferry, and, at 139, are disturbed by a vein mass of cream-colored granite, 25′–50′ thick, with large crystals of feldspar and mica and large masses of uncrystallized feldspar and quartz. A little south of 139 the schist contains nodules of feldspar and quartz and dips 25°–45° E.S.E. It makes up the whole of the cliff, here sixty feet high, "the Bonnet," dipping as high as 60° but averaging 45° E.S.E., and crossed by veins of granite. On the other side of Wesquage Beach the light and dark mica schists recur and southward to Watson's Pier and 140; dip 55°–75° E. 10° S. Numerous granite veins, from $\frac{1}{4}''$ to 3′ thick, occur among and parallel with the strata, and in everything but crystalline arrangement, which is across the veins, resemble layers. At 141, on Boston Neck, a light cream-colored granite crops out. Between 141 and Pattaquamscott River, and also at 142, on the other side, occurs a fine grained, light colored granite or gneiss. The next outcrop south is just below Narraganset (lower) Pier where a fine-grained, pinkish protogine and granite, in places probably gneiss, of pinkish feldspar, black mica or chlorite and quartz, is traversed by veins of coarse granite with reddish feldspar. This rock forms the shore for two miles; at 143, Gunning Rock, dips S.E. by E. and also E. by N., crossed by E.S.E.–W.N.W. joints. Southward it becomes finer grained and its feldspar lighter colored until near Quohog Rock it differs considerably from that of Narraganset Pier. Between 144 and Point Judith Light, two and one-half miles south, there are no outcrops. Near a bridge across the "Narrow River," a continuation of the Pattaquamscott, about one and one-half miles S.W. of South Ferry, a bed of fine-grained plumbago, said to measure about two feet was met in digging a well. Half a mile west of that place

granite or gneiss ledges occur. Jackson, on his map, indicates plumbago in granite two miles west of Bonnet Point, and the range of Tower Hill back of the river he has down as granite and gneiss.

Conclusions.

Stratigraphical.—From the stratification at 46, 53, 17, on Newport Neck, and at 143, near Narraganset Pier, it is evident that the protogine masses of that neck are not intrusive, and it is therefore improbable that that of Conanicut is so. As protogine occurs also at West Island, and thus on both sides of the Carboniferous basin, it seems highly probable that all these masses of protogine belong to the same metamorphic bed or series of beds, and that these isolated masses in the center were thrown up either before or after the deposition of the Carboniferous strata or partially at both times. No eastward dips have been observed in the eastern half of the main protogine tract of Newport Neck, but for convenience such have been assumed. If the dip is uniformly W.N.W., a fault must be assumed at Almy's Pond between the protogine and the Carboniferous beds, or an original unconformity must be supposed to have been subsequently changed to a conformity in direction, but not in angle of dip; for the metamorphism of a bed overlying carbonaceous, fossiliferous beds into protogine is highly improbable and intrusion has been shown to be out of the question.

In intimate contact with these isolated masses of protogine we find, at the Dumplings and Bailey's Beach, certain epidotic and chloritic schists, some parts of which closely resemble the chlorite schist of "Paradise," which, therefore, on lithological grounds, would, together with its associated mica schists, seem to be perhaps synchronous with the former.

The chloritic argillytes with calcite, forming the western part of Newport Neck, evidently correspond to the similar rocks of Brown's and Church's Points in Little Compton, and accordingly underlie the coal measures; and at Coaster's Harbor and Rose Islands we find them below the "Quartz and Clay Aggregate." The dotted line on the map, from Castle Hill to Rose Island, the Gull Rocks, Coaster's Harbor Island, Little Lime Rock and Brenton's Cove, bounds the probable submarine extension of these rocks near Newport. But the western boundary of this tract almost touches the chloritic and epidotic schists of the Dumplings, which dip about easterly; and the chloritic argillytes of the northern half of Newport Neck dip E.S.E.; therefore, probably, the latter overlie the former. Again, the chloritic argillytes at 71, west of Price's Neck, are underlaid by a layer of ferruginous chlorite, which occurs also

in Church's Cove, Little Compton, at the base of these argillytes and near the protogine; and a ferruginous chlorite of slightly different appearance occurs near the top of the protogine at Bailey's Beach; and it is natural that rocks abounding in chlorite should be followed by some a little less chloritic. For all these reasons the normal position of the chloritic argillytes would seem to be above the chloritic and epidotic schists of 15 and 17 and the chlorite and hornblende schists of "Paradise."

The dolomite at 94 and the Lime Rocks is associated with purple slate, and these slates belong to the chloritic argillytes, and so the dolomite. These two outcrops, as stated by Prof. Ch. Hitchcock, seem to be parts of the same bed on opposite sides of a synclinal axis. This axis may be traced northward through Coaster's Harbor Island and southward in the western part of the "Flinty Slate." The gentle S.E. dip at 43 would then represent a minor fold, and the easterly dipping lines at the Lime Rocks would be joints.

The siliceous argillyte of the middle portion of Newport Neck corresponds to that at Conanicut and Sachuest Neck, where it is associated with "Conglomerate I" and underlies the lowest distinctively Carboniferous bed. Its relation to the older rocks is not so clear. From Jackson's observations and mine it is evident that the series of (what may be provisionally termed) Pre-Carboniferous rocks is but incompletely represented at any one point. Thus at Rose Island the Carboniferous rocks rest on the chloritic argillytes, at Sachuest Neck on the siliceous argillytes, but in Conanicut directly upon the protogine. On Newport Neck the siliceous argillytes lie upon the protogine, but in Little Compton apparently the chloritic argillytes take that place. On Newport Neck the siliceous are juxtaposed to the chloritic argillytes, but their relative age is not clear. The following indications, however, throw some light on the question. The Conglomerate I associated with the siliceous argillyte at Sachuest Neck contains pieces of red jasper, and that occurs in this vicinity only in connection with the dark purple slates and dolomite of the chloritic argillyte series. At 66 the siliceous argillyte contains fragments of chloritic argillyte. The conflicting flexures throughout the region diminish the value of dip indications; but it is noticeable that the dip of the chloritic argillytes on Newport Neck is almost uniformly toward the siliceous argillytes, and that as the former nowhere come up again to complete the synclinal it may be supposed that they come up under the latter and thin out before reaching the exposed portion of the protogine on the neck. From the relative strike of the siliceous argillytes at Sachuest Neck and that of the chloritic argillytes of Little

Compton it seems probable that the former overlie the latter unless we suppose the protogine to recur under water on the east side of Sachuest Neck. Serpentine in layers and minute veins is characteristic of the siliceous argillytes, and Jackson found that in the northern part of the State chlorite and hornblende slate are followed by dolomite or serpentine, i. e. the chloritic rocks underlie the serpentines. From these data it seems somewhat probable that the true position of the siliceous argillytes with serpentine is above the chloritic argillytes with dolomite.

The lowest rocks of certain Carboniferous age, the quartz and clay aggregates of Sachuest Neck, recur at Rose, Coaster's Harbor and Conanicut Islands. Lying upon them in Mackerel Cove, and also probably at Coaster's Harbor Island, are the argillaceous schists with siderite and pyrites, in all probability belonging to the same horizon as the Easton's Point argillytes with pyrites (lower argillytes of first paper) which there underlie conglomerate II, and which, on account of their relation to Sachuest Neck, were represented in the general section as overlying the quartz and clay aggregate. At Beaver Head the great bed of quartzyte conglomerate is wanting and the coal-measures immediately follow the sideritic argillyte. Indeed, on the west side of Easton's Point, the conglomerate seems to thin out and there is some uncertainty as to where, in the vicinity of Easton's Beach, the boundary between that conglomerate and the overlying argillytes, conglomerates and carbonaceous schists should be drawn. At Coaster's Harbor Island a slightly metamorphic conglomerate occurs in close proximity to the sideritic and chloritic argillytes, which Prof. Ch. Hitchcock estimates at 50′ and places above the coal beds. If that is correct, the coal-measures must thin out at that locality. The strata of Coddington Cove, Bishop Rock and "The Cliffs" belong to the coal-measures, to which also may be assigned the carbonaceous beds of Taggart's Ferry, the Glen, and of the shore between High Hill and Brown's Points on the East Passage. Here also would seem to belong the Dutch Island and Beaver Head beds which, however, have been subjected to greater metamorphism. The conglomerate of Miantonomah Hill, both Jackson and Ch. Hitchcock regard as above the coal beds, although it strongly resembles that of Easton's Point and differs from that of Coaster's Harbor Island. I could not find the outcrops of conglomerate above the "Cliffs" series to which Professor Ch. Hitchcock alludes on the east side of Almy's Pond, and which he coördinates with that of Miantonomah Hill. What relations exist between the coal-measures of "The Cliffs" and the epidotic and chloritic schists south of Sheep Point is uncertain. A fault has been supposed and the slicken-

sides crossing the strata at Ochre Point and along "the Cliffs" point to a disturbance in a N.–S. or N.N.E.–S.S.W. line, which, if continued south, would border on the outlying masses of epidotic schist opposite 15. The recess between Ochre Point and 14 was formed by erosion of the softer beds. But this does not explain the presence of the coal-measures between the epidotic schists at 14 on the S.E. and the protogine at 44 on the N.W. Here we must resort to the supposition either of Archæan Islands and shallows in the Carboniferous estuaries, or of a double system of faults or of folds followed by erosion of the softer beds.

The mica schists of the Narraganset shore belong to a highly metamorphic belt which includes Dutch Island. A question arises as to the age of these two beds of mica schist. Those of the shore differ chiefly from those of the island by the absence of garnets and graphitic beds and the presence of veins of granite. Farther west occurs the bed of graphite associated either with these schists or with an adjoining gneiss coördinate with that of Narraganset Pier. We have then either a contact of Archæan beds, containing graphite, with highly metamorphic Carboniferous beds, containing graphitic schist, or else, both beds belong either to the Archæan or the Carboniferous. A middle ground has been taken on this question. The protogine of Conanicut and Newport differs from that of Narraganset Pier in containing two kinds or colors of feldspar; besides, the protogine at the pier is not prevalent, the rock being more generally micaceous than chloritic, whereas the opposite case exists at Newport and Conanicut. From the relative dip and position of the mica schists of Bonnet Point, etc., and of the gneiss, granite and protogine south, these mica schists would seem to overlie the latter, but if we consider them as "pre-carboniferous" a question as to their relations to the epidotic, chloritic and hornblendic schists, which in other parts succeed the protogine, arises. They may provisionally be supposed as synchronous with these or as underlying them.

In accordance with these views the accompanying geological map and section have been prepared. They continue westward, the map (Plate I), and the general section (Plate III), of the first paper,* and the following table enumerates and describes all the beds of the south end of Narraganset Bay in

* The layers of "quartz and clay aggregate" in contact with protogine in Mackerel Cove are more inclined than in the section, and the overlying sideritic argillytes are folded, in places, near the surface somewhat like the beds of Dutch Island. The coal-measures in the Western Passage are supposed to dip away from the basin rock, as was also supposed in the case of the chloritic argillytes, in the general section of first paper, at the other side of the basin, but it is a stratigraphical possibility that these beds dip against the sides of the basin as they seem to against the isolated mass of protogine in its center, and as the underlying beds (.5), in the Western Passage seem to against the mica schists (.02).

their chronological order, as far as determined, beginning with the oldest:

·01. *Granite, Gneiss, Protogine.*—Coarse and fine granite and gneiss, of black mica, more or less pinkish feldspar, and quartz, passing in some places into a protogine of chlorite, pink, or a pinkish and a greenish feldspar, and quartz, in others into a granite of light-colored mica, cream-colored feldspar and quartz. The bed of plumbago probably belongs in the gneiss. Veins of coarse, pink granite, sometimes without mica, and of cryptocrystalline, pink feldspar and quartz. One vein or seam of yellow serpentine. (West Island, Narraganset Pier, Newport, and Conanicut.) 1300′+.

·02. *Mica schist*, dark and light colored, both with black mica, the light more quartzose and with quartz pebbles. Veins of coarse granite of cream-colored feldspar, light mica and quartz. 1450′.

1. *Hornblende, chlorite* and *mica schist.*—The hornblende schist of hornblende and triclinic feldspar, sometimes with a little mica, passing into a chlorite schist of chlorite with a little calcite and possibly quartz. This alternating several times with mica schist,* the mica schist passing into a siliceous or an argillaceous schist. Veins of milky quartz with chlorite and also sometimes with crystals of feldspar, also veins of zoisite. ("Paradise" in Middletown.) 950′.

1.5. *Epidotic and chloritic schist.*—In places argillaceous, serpentine or talcose, with nodules and veinlets of crystalline epidote, massive and schistose chlorite, the chlorite schist with a little calcite; sometimes with pebbles of quartz. A few layers of ferruginous chlorite, and of quartzyte with quartz pebbles, in the lower part. Veins of cryptocrystalline pink feldspar and quartz, and of milky quartz. 400′–600′.

2. *Chloritic argillyte.*—Bluish green or dark purple schist and slate, sometimes grayish and micaceous instead of chloritic, generally with minute passages or nodules of amorphous calcite, the latter, when large, traversed by veins of crystallized calcite. Where very chloritic it contains crystals of magnetite, when less so, often cubical iron pyrites. The green slates in places with passages and large masses of white quartz, the purple ones with passages and nodules of dark purple and red jasper, and in Newport harbor with several thick layers of grayish and pinkish dolomite. Veins of milky quartz and chlorite sometimes with crystallized, flesh-colored feldspar. 500′–2000′.

* A similar series seems to occur near Providence (see Jackson, pp. 75, 76), and near New Haven (see J. D. Dana, Manual of Geology, third edition, also this Journal, III. vol. vi. On the Rocks of the Helderberg era in the valley of the Connecticut, etc.)

3. *Siliceous argillyte.*—(Flinty slate of the Hitchcocks, Primordial felsite of Shaler, Conglomerate I of first paper), dark gray, purple or green, more or less schistose, siliceous or argillaceous; in many places an impure serpentine; at Sachuest Neck with a slaty conglomerate containing a few pebbles of red jasper. Seams of precious serpentine and talc, near which calcite, picrolite and chrysotile. Veins of cryptocrystalline granite. 500′–2000′.

4. *Quartz and clay aggregate.*—A highly metamorphic, coarsely stratified, dark gray or black aggregate of very coarse quartz grains and fine argillaceous matter, including a few layers of fine, carbonaceous slate with Carboniferous plants. Annularia longifolia. Veins of milky quartz. 750′.

5. *Sideritic argillyte.*—(Lower argillaceous schist of first paper.) Light and dark gray, argillaceous, in some places hydro-micaceous or talcose, schist, generally with disseminated, minute nodules of crystalline siderite, sometimes with cubical iron pyrites, in several localities striped, light and dark, across the bedding. Veins of milky quartz with chlorite, frequently also with ferruginous, crystalline calcite. One or two veins of argillaceous rock with cubical iron pyrites. 600′–2000′.

6. *Quartzyte Conglomerate.*—(1st and 2d conglomerate of Ch. Hitchcock, Conglomerate II of first paper) consists of large pebbles and bowlders of finely stratified quartzyte with a little mica (or very quartzose mica schist), containing, in certain localities, Lingulæ, and cemented together with an argillaceous and siliceous, in places a micaceous cement containing crystals of magnetite. Veins of milky quartz. ("Paradise," "Purgatory," etc.) 750′.

7, 8, 9. *Coal measures.*—Alternating dark and light gray, argillaceous schists (sometimes ochraceous or with minute ferruginous nodules), grits, sandstones, quartzyte conglomerates (of smaller pebbles than 6), carbonaceous argillytes or slates with large ferruginous nodules, numerous species of coal plants, and beds of plumbaginous anthracite. At Dutch Island the argillaceous schists are replaced by garnetiferous, mica schists including a few layers of garnetiferous, hornblende or chlorite schist.* Veins of milky quartz, rarely with chlorite, at Dutch Island both hyaline and milky, with feldspar. 2000′.

These beds give a total thickness of from 9,200 to 13,800 feet, or, supposing 1 to be synchronous with 1.5, of 8,250′ to 12,850′. Of these only Nos. 4–9, or 3700′–4100′, are certainly of Carboniferous age. Professor Shaler assigns No. 3 to the Primordial, but it is unfossiliferous as are all below 4. Prof. Hunt refers 2 and 3 to the Huronian. Mr. W. O. Crosby,

* At the Portsmouth coal mines, in this basin, crystallized siderite, marcasite and calcite, as well as graphite and asbestos, occur in proximity to the coal beds.

after studying certain hornblendic and chloritic rocks in Rhode Island and Massachusetts, and examining the granite near Tiverton,* is disposed to assign them to the Montalban; and as these rocks present some analogies to .01, 1 and 1.5, his opinion is of weight here, but the metamorphic character of the whole series, including the coal-measures, should make us cautious in the application of chemical methods of classification which might be valid in a region where the Carboniferous beds had preserved their normal constitution.

An analysis of 200 measurements of the dip at the south end of the bay yields these results: There are 12 different directions of the dip: A, W.N.W.–E.S.E.; A″, W.–E.; B, N.N.E.–S.S.W.; B″, N.E.–S.W.; B‴, N.–S.; C, N.N.W.–S.S.E. Of these, A″, B″, B‴, varying but 22° one way or the other from A, B, C, may be attributed to minor causes, leaving three main flexures 45°–90° apart. As none of the twelve dips are confined to the Pre-carboniferous beds the flexures must all have taken place, to some extent at least, as late as the close of the Carboniferous age. The most prevalent ones are A and B, the former giving a strike of N.N.E.–S.S.W. (or N. 33 E.–S. 33 W. true), parallel with the Appalachian range and, therefore, probably dating to the time of the Appalachian revolution, the latter one of W.N.W.–E.S.E. (or N. 57 W.–S. 57 E.) at right angles to that range. This last was in all probability the cause of the W.N.W.–E.S.E. fissures which characterize the whole region, especially the quartzyte conglomerate.† Two main synclinal axes running N.N.E.–S.S.W. are apparent, one between the Narraganset shore and the southern part of Conanicut, another between the chloritic argillytes and the protogine on Newport Neck which may be traced northward through Coaster's Harbor Island. These flexures traverse the entire series with little regard to their lithological character. As the same bed is often flexed in several directions it is not easy to determine whether unconformable deposition took place anywhere. What appears like unconformity is often the result of lateral pressure and faulting, but, as there is some reason to suppose that the protogine and associated schists in the center of the basin were above water in Carboniferous times, it seems probable that on their borders the Carboniferous beds must lie unconformably, but the highly metamorphic character of the protogine and the subsequent flexure of the entire series has obscured the evidences of it. The irregular vertical distribution of the members of the Pre-carboniferous points either to flexures in those more ancient times, or to changes or differences in the character

* Geology of Eastern Massachusetts. Boston Society of Natural History, 1880, pp. 107, 108, 127, 133, 134.

† Professor Ch. H. Hitchcock notes the complex dips at the coal mines, p. 127.

of the sediments within short distances, or erosion of them, or else to different degrees of metamorphism of the same bed. This last has been erroneously supposed to account for the difference between the chloritic and siliceous argillytes. Whatever may have been the cause, the fact is that the Carboniferous strata lie immediately upon as many as six different kinds of beds at different points. That metamorphism took place in part before the deposition of the Carboniferous beds is possible but not to such an extent as to prevent the subsequent flexure of the whole series; that it took place unequally at different places in later Carboniferous times is probable from a comparison of the Dutch Island and Newport beds. The entire series of beds, with the different veins, affords a succession of lithological and mineralogical facts which can hardly fail to be suggestive to the chemical geologist.

Physiographical.—In attempting to reconstruct the physiography of Carboniferous times in this region we may venture the supposition that the ancient shore, on the east, followed the line now indicated by the range of granite hills trending south from Tiverton towards West Island, and, on the west, that indicated by the corresponding range of Barber's Height and Tower Hill, fifteen miles distant in North and South Kingstown, which trends southward toward Point Judith. A little more than midway from the east shore of this basin, we may suppose, was an island of protogine, siliceous and chloritic argillyte (or of the rocks which these now represent), about four miles in diameter, covering what is now part of Conanicut, Newport Neck and harbor. The rest of this end of the basin, with perhaps an exceptional islet at "Paradise," was alternately marsh or estuary, but in its eastern half was at one time either the theatre of powerful or long continued, local, erosive influences operating on some protruding quartzytes, or else afforded a channel for stone-laden ice floes or powerful currents bringing detritus from the north. The plowing out of the east, west and central passages of Narraganset Bay, as well as of Mackerel Cove and the smaller inlets between Easton's Point and "the Cliffs," on one side, and Sachuest Neck, on the other, and the lands back of them, with so little regard to anticlinal or synclinal axes, may be attributed, as suggested by Professor Shaler, in part to pre-glacial, but largely to glacial erosion.

Newport, R. I., December, 1883.

Art. XXXIII.—*On Mesozoic Dicotyledons;* by Lester F. Ward.

In the following remarks on Mesozoic Dicotyledons, I confine the term *Dicotyledons* to that sub-class of the vegetable kingdom which is embraced under the term *Angiosperms* in most modern text-books of botany. This is the usage of most vegetable paleontologists[1] and the reasons for adopting it have been frequently stated.[2]

The Dicotyledons occupy somewhat the same position in the history and development of plants that the Mammalia occupy with respect to animals. They constitute the dominant type and in their rapid march have now so completely gained the ascendant as to dwarf all other forms into relative insignificance. They include nearly all the deciduous forest trees, the shrubby undergrowth, the leafy herbage and the weeds of all temperate regions.

But this has not always been the case. In fact the reign of the Dicotyledons, geologically considered, has been very brief. Although there is evidence that the earth has been covered with vegetation since the beginning of the Carboniferous age at least, still there is nothing to warrant us in saying that a single dicotyledonous plant existed prior to the close of the Jurassic. Indeed, we do not know from the actual discovery of specimens that this type appeared earlier than the second recognized group of the Cretaceous—the Urgonian. Until quite recently the presence of these plants in formations lower than the Miocene was so rare that it was with the Tertiary rather than with the Cretaceous that the existing dominant vegetation of the globe was assumed to have originated.

Notwithstanding this, some of the earliest, if not the very earliest, discoveries of these forms were in cretaceous strata. In the stone-quarries of the Harz mountains near Blankenburg, were found, near the beginning of the eighteenth century, prints of large leaves which the workmen believed to be those of the grape vine, and which were mentioned by Scheuchzer, Brückmann, and Walch, but without any attempt at their scientific determination.

A brief historical review of the discovery, identification and publication of dicotyledonous species in Cretaceous strata of Europe and America, including the arctic regions, will show the importance which this subject is assuming among paleontologists.

[1] Göppert, Geinitz, and one or two others conform to the Jussiæan system.
[2] See the American Naturalist, vol. xii (June, 1878), pp. 359–378.

In 1833 Zenker[3] took up in earnest the study of the Blankenburg leaf-prints and described, figured and named five species belonging to two genera. One of these genera he rightly concluded to have no living representatives, and he therefore named it *Credneria*, after his friend Professor Credner, who collected the specimens.

In 1841 Göppert[4] figured a number of dicotyledonous leaves from the Quadersandstein of Silesia, but did not venture to give names to them.

The next year Geinitz[5] identified three species in the lower Quader of Saxony at Niederschöna, the fossil flora of which place was so well worked up by Ettingshausen in 1867.

In 1845 Corda[6] figured some dozen leaves from Trziblitz, Luschitz, Perutz, and Weberschan, in Bohemia, some of which localities he placed in the Gault, but they are probably all in the Lower Quadersandstein, or Cenomanian. He made no attempt to refer these forms to genera and species.

Unger's *Synopsis*[7] appeared the same year, in which sixteen species of Cretaceous Dicotyledons are recognized down to that date. Göppert,[8] however, admitted only thirteen species in his table published in Bronn's *Naturgeschichte*, which also appeared in 1845.

Debey[9] in 1848 enumerates sixteen species as previously published and adds to these twenty-seven others from the neighborhood of Aix-la-Chapelle, most of which, however, he contents himself to call *Phyllites*, and as no figures were made, it is probable that some of these were not Dicotyledons. He also gives four *Carpolithes* which he identifies with dicotyledonous orders.

The same year Göppert[10] published a supplement to his Flora of the Quadersandstein in which a number of Dicotyledons are recognized.

In Ettingshausen's *Proteaceen der Vorwelt*, 1851,[11] four Creta-

[3] Beiträge zur Naturgeschichte der Urwelt, von Jonathan Carl Zenker. Jena, 1883.

[4] Ueber die fossile Flora der Quadersandsteinformation in Schlesien, etc., in Nova Acta Naturæ Curiosorum, vol. xix, Taf. xlvii, li, liii.

[5] Characteristik der Schichten und Petrefacten des sächsisch-böhmischen Kreidegebirges, von Dr. Hans Bruno Geinitz. Heft 3, Dresden and Leipzig, 1842, p. 97.

[6] In: Die Versteinerungen der böhmischen Kreideformation, von Aug. Em. Reuss. Stuttgart, 1845–46, Taf. l, li.

[7] Synopsis plantarum fossilium autore Fr. Unger, M.Dr., Lipsiæ, 1845.

[8] Naturgeschichte der drei Reiche, xv, 2 (Handbuch einer Geschichte der Natur, iii, 2) von Heinrich G. Bronn, Stuttgart, 1849, pp. 44–57 and 66.

[9] Uebersicht der urweltlichen Pflanzen des Kreidegebirges überhaupt und der Aachener Kreideschichten insbesondere, von Dr. M. Debey, in Verhandlungen des naturhistorischen Vereines der preussischen Rheinlande, 5. Jahrgang 1848, p. 113.

[10] Zur Flora des Quadersandsteins, in Nova Acta Nat. Cur. xxii, 1, p. 365.

[11] Sitzungsberichte der mathem.-naturw. Classe der kaiserlichen Academie der Wissenschaften, Wien. Bd. vii, Heft iv, 1851, p. 711.

ceous species are enumerated, and Von Otto[12] in his *Additamente*, 1852—54, also described Proteaceæ from the Quader of Saxony; while Miquel[13] in 1853 described a few Dicotyledons from the upper Cretaceous of Limburg.

In 1856 Dunker[14] described and figured in the *Palæontographica* four species from Blankenburg in addition to those of Zenker, and one cluster of fruit which he believed to belong to *Credneria*, and to indicate strongly that those ancient plants belonged to the Polygonaceæ, Zenker had divined that they might be amarantaceous.

One year later Stiehler[15] reviewed in the *Palæontographica* the whole subject of the Cretaceous flora of the Harz mountains, and added to all previous results the discoveries made by Hampe, a druggist of Blankenburg, in the marls near that place. Out of the numerous forms of *Credneria* he carves a new genus which he calls *Ettingshausenia*, and of which he makes eight species. He admits seven species of *Credneria*, and figures several others which he calls new species, but without assigning specific names to them.

Thus far America had contributed nothing to the flora of the Cretaceous, but in 1858 Heer described in the proceedings of the Academy of Natural Sciences of Philadelphia[16] eight species of Dicotyledons which had been collected by Doctor Hayden in Kansas and Nebraska. These, however, he erroneously believed to be Miocene.

The next year Mr. Lesquereux[17] contributed a paper to this Journal in which a number of fossil plants from Nanaimo, Vancouver's Island, and from Bellingham Bay were described as Miocene. It is now known that Nanaimo is Cretaceous, and his paper enumerates six species of Dicotyledons from that locality.

Nothing further appears to have been done until 1863, when Dr. Newberry[18] reported, in the Boston Journal of Natural History upon certain fossil plants from Orcas Island, British Columbia, collected by the Northwest Boundary Commission. He

[12] Additamente zur Flora dis Quadergebirges in Sachsen, von Ernst von Otto. Heft ii, Leipzig, 1854, p. 44.

[13] De fossile planten van het Krijt in het hertogdom Limburg, Haarlem, 1853. Verhand. Geol. Kaart Nederl. i, pp. 33–56.

[14] Ueber mehre Pflanzenreste aus dem Quadersandsteine von Blankenburg, von Wilhelm Dunker. Palæontographica, iv, 1856, pp. 179–183, tab. xxxii–xxxv.

[15] Beiträge zur Kenntniss der vorweltlichen Flora des Kreidegebirges im Harze, von August Wilhelm Stichler. Palæontographica, v, pp. 45–80, Taf. ix–xv.

[16] Fossil Plants of the Lower Cretaceous beds of Kansas and Nebraska, by Oswald Heer. Proc. Acad. Nat. Sci. Phil., 1858, pp. 265, 266.

[17] On some fossil plants of recent formations, by L. Lesquereux, Am. Journ. Sci., II, xxvii, 1859, pp. 359–366.

[18] Descriptions of fossil plants collected by Mr. George Gibbs, Geologist to the U. S. Northwest Boundary Commission under Mr. Archibald Campbell, U. S. Commissioner, by J. S. Newberry. Boston Journ. Nat. Hist., vii, 1863, pp. 506–524.

declared the horizon Cretaceous, and among the plants described were four Dicotyledons.

In 1866 appeared the somewhat famous *Phyllites crétacées du Nebraska* of Capellini and Heer,[19] the latter of whom determined the fossil plants which the former had himself helped to collect at Blackbird Hill, Nebraska, in the now well known Dakota Group. The Cretaceous character of these fossils was here rather grudgingly conceded and has never since been seriously doubted.

While America had been thus coming forward Europe had remained in the background for about ten years, or since Stiehler's monograph of the Harz in 1857. It was not till 1867 that Ettingshausen[20] published in the Sitzungsberichte of the Vienna Academy his valuable paper on the fossil flora of Niederschöna in Saxony. The horizon of this place is considerably lower than that of Blankenburg and belongs at the base of the Quadersandstein formation of Germany. Nevertheless, the species nearly all belong to living genera—Quercus, Fagus, Ficus, Laurus, Protea, etc. Twenty-eight species are enumerated.

In the same volume Unger[21] described and figured four Dicotyledons, thus far unknown, from the Gosau (upper Senonian) of Austria, at St. Wolfgang and Neue Welt. Though contenting himself to call them all *Phyllites*, he yet ventured to assign two of them to the Magnoliaceæ and two to the Proteaceæ.

Returning to America, we find in 1868 the two most important contributions yet made in this country to the Cretaceous flora of the west. These were Dr. Newberry's *Notes on the later extinct floras of North America*, published in the Annals of the New York Lyceum of Natural History (April),[22] and Mr. Lesquereux's paper in this Journal[23] for July of the same year. Though prepared quite independently of each other, these two papers followed the same method and reached the same results. Both authors give lists of the American Cretaceous species known up to that date, Dr. Newberry enumerating 20 and Mr. Lesquereux 21 Dicotyledons. The number of species described

[19] Verhandl. d. schweiz. Gesellsch. d. Naturf. Zurich, 1866.

[20] Die Kreideflora von Niederschoena in Sachsen, ein Beitrag zur Kenntniss der ältesten Dicotyledonengewächse, von Const. Freih. v. Ettingshausen. Sitzb. lv, Abth. 1, pp. 235–264, Taf. i–iii.

[21] Kreidepflanzen aus Oesterreich, von Dr. F. Unger, l. c. pp. 642–654, Taf. i, ii.

[22] The figures corresponding in the main to the species here described were published in separate form by the U. S. G. and G. Survey of the Territories, F. V. Hayden, Geologist-in-charge, under the title: "Illustrations of Cretaceous and Tertiary Plants of the Western Territories of the United States," which did not appear until 1878.

[23] On some Cretaceous fossil Plants from Nebraska, by L. Lesquereux. Am. Journ. Sci., II, xlvi, 1868, pp. 91–105.

by Dr. Newberry as new was 45, and the number by Mr. Lesquereux was 47. Nine species from Fort Ellsworth, Kansas, included in Mr. Lesquereux's list, the descriptions of which did not appear until the following year,[24] do not enter into the figures above given. It will thus be seen that about seventy-five species of Dicotyledons had been described from the Dakota Group and other American Cretaceous strata down to the year 1869.

Far less could be said for Europe at this date. Hosius,[25] in 1869, was able to enumerate in his *Geognosie Westfalens* twenty-five characteristic species of the Quadersandstein, which had been described and figured either by Von der Marck[26] or by himself.[27] In this year, too, Heer published his *Fossil Flora of Moletein in Mähren*, which belongs to the lower Quadersandstein, or base of the Cenomanian. Twelve species are described and carefully figured.

In Hayden's annual reports of the geological survey of the Territories for 1870 and 1871[29] Lesquereux continues to enlarge the list of American species, and in 1872, Heer,[30] in his *Fossil Flora of Quedlinburg* makes further additions to that of Europe.

We are thus brought down to the year 1874, which is marked by three very important publications.

Schimper's *Traité de Paléontologie Végétale* was completed in that year, in the fourth volume[31] of which 109 species of Cretaceous Dicotyledons are recognized. Of these 46 are American, which shows that the author was far behind in the literature of the subject. He also expresses serious doubts as to the Cretaceous age of these plants, although this had been long settled here beyond a peradventure.

Next should be mentioned Heer's *Kreideflora der Arctischen Zone*, which appeared in 1874 in volume three of his *Flora Fossilis Artica*. In this work he describes one solitary dicotyledonous species (*Populus primæva*) in the schists of Kome—Urgonian—by far the most ancient form thus far met with, and 33 species in the higher strata of Atane, which are now gener-

[24] On fossil leaves from Fort Ellsworth, Nebraska. Transactions of the American Philosophical Society, Philadelphia, vol. xiii, new series, pp. 430–433, pl. xxiii.

[25] Die in der Westfälischen Kreideformation vorkommenden Pflanzenreste (Beiträge zur Geognosie Westfalens), von A. Hosius. Münster, 1869.

[26] Fossile . . . Pflanzen aus dem Plattenkalk von Sendenhorst. Palæontographica, xi, 1865.

[27] Ueber einige Dicotyledonen der westfälischen Kreideformation, Palæontographica, xvii, 2, pp. 89–104, Taf. xii–xvii.

[28] Beiträge zur Kreideflora. I. Flora von Moletein in Mähren. Zurich, 1869.

[29] On the fossil plants of the Cretaceous and Tertiary formations of Kansas and Nebraska, Ann. Rep. 1870, p. 370. Fossil Flora, Cretaceous Strata, Kansas. Ann. Rep. 1871, p. 301.

[30] Beiträge zur Kreideflora. II. Zur Kreideflora von Quedlinburg.

[31] Pp. 677–679.

ally believed to correspond with the Cenomanian of Europe. These researches of Heer appeared too late to be embodied in Schimper's great work.

Finally, as crowning this fruitful year's labor, appeared Mr. Lesquereux's important quarto volume on the "Cretaceous Flora of the Western Territories,"[32] reviewing the results of all previous researches in this country, and describing and illustrating 107 species of American Cretaceous Dicotyledons. In Hayden's annual report for the same year[33] 26 species are described and some figured, but most of these were also more fully treated in the *Cretaceous Flora.*

During the succeeding six years little activity was manifested in this field, the attention of paleobotanists being principally directed to the floras of later formations, but in 1880 Hosius and Von der Marck published in the *Palæontographica*[34] their *Flora der westfälischen Kreideformation,* an important work reviewing the entire Cretaceous flora of Westphalia. Although fossil plants had been found throughout almost the entire Cretaceous series as there represented, still it was only in the Senonian that any Dicotyledons were detected. At two quite distinct horizons within the Senonian such plants were found, 37 species being credited to the upper and 24 to the lower Senonian, or 61 species.

Quite an important paper by Dr. Debey appeared in 1881[39] describing certain very interesting querciform leaves from the sands of Aix-la-Chapelle. Fifteen species are described and well illustrated, all of which are referred to *Dryophyllum,* a genus founded long ago by Debey on unpublished material and to which Saporta refers four of the forms from the travertines of Sézanne. It had been announced[40] that Debey had collected in the vicinity of Aix-la-Chapelle no less than two hundred species of dicotyledonous plants, and it is to be hoped that this paper may form a beginning, at least, of the much-needed work of acquainting vegetable paleontologists with the nature of this remarkable flora.

The sixth volume of Heer's *Flora Fossilis Artica* appeared in 1882. In this the Cretaceous flora of Kome and Atane are reviewed with fresh materials. While unable to find any com-

[32] Contributions to the Fossil Flora of the Western Territories, Part I. The Cretaceous Flora. By L. Lesquereux, being Report of the U. S. Geological Survey of the Territories, F. V. Hayden, Geologist-in-charge, vol. vi. Washington, 1874.

[33] Pp. 271–365, pl. i–viii.

[34] Vol. xxvi, 1880.

[39] Sur les feuilles querciformes des sables d' Aix-la-Chapelle, par M. Debey. Bruxelles, 1881. (Compte rendu du Congrès de botanique et d' horticulture, 1880.)

[40] Schimper, Traité de Paléontologie Végétale, Paris, 1869–1874. Tome iii, pp. 671, 673.

panions for the solitary *Populus* of Kome, he adds largely to the dicotyledonous flora of Atane. From 33 species in 1874 this flora now rises to 95. In the seventh volume of the same work, which unfortunately must now be the last, a new Cretaceous flora is announced, that of Patoot, also in Greenland, which is regarded as extreme upper Cretaceous. Dicotyledons here abound and no less than 74 species are made known in Heer's work.

Within the past few months an important paper has been contributed to the Royal Society of Canada by Principal Dawson,[35] in which 30 species, mostly new, from two distinct horizons of the Cretaceous of British Columbia are described and figured.

Lastly I am able to add to this enumeration one of the most important works that has ever been produced on vegetable paleontology, but which is still unpublished, though now ready for the press. I refer to Mr. Lesquereux's *Cretaceous and Tertiary Floras*, which is to form the eighth volume of the series of quartos of the U. S. Geological Survey of the Territories in charge of Dr. F. V. Hayden. In this work the author again exhaustively reviews the entire subject of the American Cretaceous flora, and we find the number of Dicotyledons thus far yielded by the Dakota Group to have reached 167. In his table of distribution he attempts to embrace the flora of the entire Cenomanian formation, to which he doubtless rightly believes our Dakota Group to belong. The total number of Dicotyledons thus marshaled is 312. Large as these figures seem, there is much reason to believe that they fall in both cases considerably below the actual state of science at the present time; as will be seen by the tabular statement given below.

If we now turn from this strictly chronological enumeration to a consideration of the stratigraphical position in which these plants have been found, as indicating their relative age, we shall find the results no less interesting than is the history of their discovery.

The various countries of the globe where geology is studied have adopted divisions for their geological formations corresponding to the character of the rocks in each country. These divisions cannot be made to harmonize with exactness when it is sought to compare widely separated regions. The attempt here made to correlate the sub-divisions of the European, Arctic and North American Cretaceous can therefore at best only lay claim to approximate accuracy.

[35] Transactions, pp. 15–34, pl. i–viii.

The Quadersandstein of Germany, in which the greater part of the European fossil plants have been found, is an extensive formation, reaching in Saxony and Bohemia from the lower Cenomanian to the White Chalk, or upper Senonian. Its middle portion is occupied by the Pläner sandstone and Pläner marls, which extend downward into the upper Cenomanian and upward to the base of the Senonian. The somewhat local character and indefinite boundaries of the Quader formations have rendered it customary on the Continent, even with German geologists, to adopt the system of d'Orbigny as now modified and to speak of the Cenomanian, Turonian and Senonian instead of Lower Quader, Pläner and Upper Quader, and it is also now common to apply these terms to formations in other parts of the world which are supposed to occupy the same stratigraphical positions.

The leading European localities from which Cretaceous Dicotyledons have been collected are: Saxony (Niederschöna), Moravia (Moletein), Bohemia (Trziblitz, Perutz), Silesia (Oppeln, Tiefenfurth), the Harz district (Blankenburg, Quedlinburg), Westphalia (Legden, Sendenhorst), and the vicinity of Aix-la-Chapelle. The first four of these localities belong to the lower Quadersandstein, or Cenomanian, that of Niederschöna lying near its base. The Cretaceous of the Harz district is probably lower Senonian. In Westphalia, Hosius and Von der Marck find fossil Dicotyledons at two different horizons, both of which, however, they place in the Senonian. The region about Legden, Ahaus, Haltern, etc., is regarded as lower Senonian, while Sendenhorst, Haldem, etc., are said to be upper Senonian. The iron-sand near Aix-la-Chapelle is probably still higher and occupies the extreme upper Senonian.

The next greatest source, outside of the United States, of the class of fossils under consideration is Greenland. The Kome beds, as already remarked, are distinctly fixed in the Urgonian, which is lower Cretaceous, and lies between the Neocomian and the Gault. The discovery of a dicotyledonous plant at this horizon is one of the most interesting facts of paleontological science. The beds of Atane, where the greater part of the species were found, although called upper Cretaceous by Heer, are admitted by him to exhibit in their fossil remains so close a relationship with the American Dakota Group as to render it probable that they are of the same age. Patoot, on the other hand, is set down as extreme upper Cretaceous, and Heer says that its invertebrate fauna indicate its identity with the Fox Hills of our Western Territories.

The localities in British Columbia from which Cretaceous Dicotyledons have come are all regarded by the Canadian geologists as upper Cretaceous. The inland portions, situated

on the Pine and Peace rivers, are said by Dr. Dawson to correspond to the Niobrara of the northwestern United States, which he also correlates with the lower Senonian of Europe. Vancouver's Island and the localities on the Pacific coast are higher and are placed in the upper Senonian, though he does not correlate them with any of the groups of American geologists. Fossil plants were found on the Bow and Belly river which is said to agree with the Pierre Group but the dicotyledonous remains appear to have been indistinct and indeterminable.

With the exception of the Dakota Group, which is commonly regarded as Cenomanian, and in which such a profusion of dicotyledonous vegetation is embedded, no fossil plants have thus far been described from the Cretaceous of the western Territories. Nevertheless, I have myself collected and brought to Washington the past season some dicotyledonous leaves from a locality on the upper Missouri river some seven miles below Coal Banks, whose position is fixed with certainty in the Fort Pierre Group, No. 4 of Meek and Hayden, which Dr, C. A. White regards as merely forming the lower portion of the Fox Hills. The material thus obtained, though meager and fragmentary, is sufficient to render it quite certain that we here have forms nearly allied to *Platanus latiloba* of Newberry (*Sassafras mirabile* Lesqx.) and perhaps connecting this with *Platanus nobilis* Newby., from the Laramie strata that overlie these beds, as well as forms resembling *Quercus salicifolia* Newby., and other Cretaceous genera and species. There is therefore ground for hoping that when this and other similar localities are thoroughly studied a new Cretaceous flora may come to light in the northwest.

I have in this paper intentionally omitted all consideration of the great Laramie group although this is regarded by many as Cretaceous. This is because it seems at least to be more recent than any of the European, Arctic or British American plant-bearing beds, while its abundant flora consists in large part of types represented in the Miocene of Europe.

It thus appears that throughout both hemispheres the conditions required for the preservation of vegetable remains in Cretaceous time have existed in a marked degree during two epochs only, the Cenomanian and the Senonian, separated from each other by a period, perhaps equal to either, during which marine forms of animal life are chiefly found. A few Dicotyledons only occur in the Turonian of Europe, as e.g. *Magnolia telonnensis* from Toulon, while the Colorado Group (Fort Benton, Niobrara) of our Western Territories has thus far proved destitute of plant life.

If now we take up the several subdivisions of the Cretaceous formation in their stratigraphical order, beginning with the

lowest, we shall see that in the Neocomian, or lowest member, no plant remains of the sub-class we have been studying have as yet ever been detected.[36]

In the Urgonian, or next higher group, one species, *Populus primæva* Heer, has been collected at Pattorfik in Greenland. In volume vi of his *Flora Fossilis Arctica*, which appeared in 1882, or eight years subsequent to the original description of this plant, Heer continued to adhere to this species as well as to its anomalous stratigraphical position.

The Gault, like the Neocomian, has thus far furnished no Dicotyledons, though not always destitute of plant remains.[37]

It is with the Cenomanian that there seems to have burst in upon the world a great and luxuriant dicotyledonous vegetation. It is found alike in Saxony, Bohemia, Silesia, in Greenland and in the western United States. Upwards of three hundred and fifty species, representing all three of the divisions of the sub-class (*Apetalæ*, *Polypetalæ*, *Gamopetalæ*), and consisting chiefly of living genera have been described.

It was formerly supposed that the beds at Blankenburg occupied a much lower position than that to which I have assigned them, and such as would place them in the Turonian, at least, if not in the Cenomanian, and Mr. Lesquereux, in the large and important work which is about to appear,[38] includes the species of Heer's Quedlinburg Flora in his table of distribution of the Cenomanian. It is now quite certain, however, that the Cretaceous of the Harz district is much higher, and authorities seem to agree in placing it in the lower Senonian. On the other hand the upper boundaries of the Cenomanian in France and elsewhere are somewhat imperfectly established. For this and other reasons I have felt justified in relegating the few species that have been classed as Turonian to the Cenomanian, of which great group they seem to be but straggling outliers.

In the Senonian, both in Europe and in British Columbia, two quite distinct horizons for fossil plants seem to occur, separated from each other by a considerable interval. In view of this I have attempted to divide this group into two horizons and am thus able to show the lower and upper Senonian separately. From the lower Senonian we have about eighty species and from the upper about one hundred and eighty.

[36] The supposed Neocomian Dicotyledons of Russia (Eichwald, Lethæa rossica, ii, pp. 58 et seq.) are shown by Heer (Fl. foss. arct. iii, Theil 2, S. 26) to come from the lower Senonian corresponding to the Harz district.

[37] Heer assigns the plant-beds of Spitzbergen to the Gault (l. c. S. 24), and Coemans finds nine new spacies of fossil plants in the Cretaceous of Hainaut (Mém. de l'acad. Royale de Belgique, xxxvi, 1867) which Briart and Cornet (l. c. xxxiii, p. 46) placed in the Gault.

[38] Cretaceous and Tertiary Floras. Report of the U. S. Geol. Survey of the Territories, vol. viii. Washington, 1883.

The following table exhibits the number of dicotyledonous species thus far recognized in each of the groups of the Cretaceous for the four principal geographical areas within which they have been collected:

Cretaceous Dicotyledons.

Geological Position.	Europe.	Greenland.	British America.	United States.	Total.
Upper Senonian	81	74	24	--	179
Lower Senonian	67	--	14	--	81
Turonian	--	--	--	--	--
Cenomanian }	53	114			351
Dakota Group }	--	--	--	184	
Gault.	--	--	--	--	--
Urgonian	--	1	--	--	1
Neocomian.	--	--	--	--	--
Total	201	189	38	184	612

As all the plants with which we are here concerned are found in the Cretaceous some may be surprised that this paper should have been entitled *Mesozoic* rather than *Cretaceous* Dicotyledons. The reason for the title chosen is simply that it may tend somewhat to enlarge the view of the true history and age of this great type of vegetation. When we see that more than three hundred and fifty species of fully developed Dicotyledons, implying the existence of many more, were flourishing in all their present luxuriance in the middle Cretaceous, and that even in the lower Cretaceous one species is known to have existed belonging to a genus that still survives, we cannot if we would, repress the thought that the ancestors of these forms must have come down through older periods of the Mesozoic.

That we shall ever discover the true progenitors of the known Dicotyledons it is, of course, impossible to say, but that they had progenitors science no more hesitates to assume than any one would hesitate to assume that a foundling child must have had parents. Moreover, such is the slow and secular character of the development of living forms on the globe that no one would suppose it possible for so prominent a group of plants as were the Dicotyledons in the Cenomanian age to have attained that condition in anything short of a vast geologic period.

It is to be hoped that we are at last approaching the beginning, at least, of a solution of this truly great problem of the origin of the Dicotyledons. I have myself seen at least one slight, it may be, but very interesting sign of possible progress in this direction. Certain quite defective, but very instructive, specimens collected in the upper Jurassic of Virginia by Professor Wm. M. Fontaine, and which he kindly brought to

Washington for my inspection, certainly possess all the essential elements of dicotyledonous leaves, although at the same time bearing a certain recognizable stamp of the cryptogamic and gymnospermous vegetation that characterizes that earlier age. What is to be the final verdict of science upon these forms cannot now be told, but it is to be hoped that the Mesozoic strata, not only in Virginia, but in all parts of the world may be diligently searched and the materials carefully studied, with a view to discovering these certainly merely "missing links" of a chain that can but have been once complete.

It is remarkable that both in its flora and its fauna the life of this continent has been thus abruptly truncated. The sudden irruption of a perfectly developed mammalian fauna at the beginning of the Tertiary is not less astonishing than the appearance unannounced of many hundreds of species of highly organized dicotyledonous plants in the middle Cretaceous. The advocates of special creation, and likewise the hunters after a lost Atlantis, were they informed upon the facts which science itself so plainly teaches, could ask no stronger argument for either of their positions. But such persons are usually not so informed, and it seems almost impossible for them to become so and still hold such views, for, fortunately, knowledge is a poison that contains its own antidote, and the very possession of the facts suffices to preclude a perverse use of them.

ART. XXXIV.—*On the Tourmaline and Associated Minerals of Auburn, Maine;* by GEORGE F. KUNZ.

[Read before the American Association for the Advancement of Science, at Minneapolis, August, 1883.]

IN 1868, the Rev. Luther Hills called attention to a specimen of tourmaline found by Mr. G. C. Hatch on the farm of the latter. At this time some work was done, but only one crystal being found, which was cut into a fine 2 kt. light green gem, the locality was abandoned on the ground that the deposit was probably a superficial one. (See The Tourmaline, by Dr. A. C. Hamlin, pp. 72, 73). After this considerable searching was made and some blasting was done, and in 1883, Mr. N. H. Perry, of South Paris, found the tourmaline in place. The locality is Mount Apatite, which is about four miles north of west of the cities of Lewiston and Auburn, Maine. The work to date, [January, 1884,] has all been carried on in a space twenty by eight feet, and to a depth of eight feet. Nearly 1500 crystals

have been found, from very small ones 10^{mm} to the largest one 105^{mm} long. They differ in general appearance from the other Maine tourmalines, and are as a rule somewhat lighter in color and of more brilliant polish. They are found colorless, light pink, light blue, light puce colored, bluish pink, and light green, and at times nearly all these colors are found in one crystal. As a rule sections show the characteristic variety of color, such as blue and pink, green and pink, colorless and green or pink, or bluish, when viewed through the length of the crystal. Some of the faintly colored crystals afforded gems that deepened very much in color after cutting.

The crystals are generally hemimorphic, terminated with a modified pink cap at one end, and at the other with a basal termination which is often white, and either loose in the cavities, or else on, and oftentimes penetrating, smoky quartz and feldspar. The majority of the crystals were more or less flawed. Faces commonly observed are: *O*, *R*, $-\frac{1}{2}$, *I*, *i*-2.

Lepidolite was found in some abundance, in distinct isolated hexagonal crystals implanted in layers on masses of this mineral, or on crystals of quartz and feldspar. Although not sharply enough defined for good measurements, they are the finest crystals of this mineral that I have as yet observed from any locality. In size they vary from 1^{mm} to 8^{mm} in width, and from 1^{mm} to 15^{mm} in length, and large masses of parts of crystals 30^{mm} to 40^{mm} in width have been observed.

The *apatite* is finer in color and form than any as yet observed at any American locality. It occurs light pink, purple, light blue, blue-green and green, and the luster and transparency are so perfect as to resemble at times the tourmaline found with it. Some were sold as gems by the enthusiastic local collectors, although the softness renders it unfit for that purpose. Faces observed commonly, are *O*, $\frac{1}{2}$, 1, 1-2, 2-2, *I*, *i*-2. The crystals occur singly or in small groups, and vary in size from 1^{mm} to 15^{mm} in length, and from 1^{mm} to 20^{mm} in width.

The *quartz* occurs in crystals which are smoky in color and nearly 200^{mm} long. These and nearly all the crystallized quartz here are capped or coated with a white opaque coating, and the large quartz crystals are at times penetrated by the colored tourmalines.

The *albite*, which resembles the cleavelandite, of Chesterfield, Mass., occurs here in abundance, in plates piled together and forming irregular and triangular spaces. In these spaces and on the sides of the crystals are found implanted nearly all the minerals described.

The other associated minerals are orthoclase, beryl, garnet, cassiterite, gummite, autunite, muscovite, leucopyrite, cookeite,

biotite, amblygonite, zircon and a mixture of orthoclase and quartz forming a graphic granite.

To Mr. N. H. Perry much credit is due for his care and zeal in developing this locality, and I am indebted to him for his kindness in furnishing all the information at his command, and for loaning specimens without obligation to purchase.

August, 1883.

Art. XXXV. — *On Andalusite from Gorham, Maine;* by George F. Kunz.

[Read before the American Association for the Advancement of Science, August, 1883.]

At Gorham, Maine, on the shores of Sebago Lake, some excavating was done for a road about one year ago, and in a mass of rock thrown out in blasting, Mr. Hayden, of Raymond, Maine, found the specimens of andalusite now exhibited. These crystals, for perfection, color and size, are equal to those found at any known locality where this mineral does not occur in gem form. The color is mostly a brownish flesh tint and at times the pink hue fades to a faint grayish pink. The crystals are opaque but translucent in pieces of from 3^{mm} to 5^{mm} in thickness. A broken crystal measured 90^{mm} (*a*), 53^{mm} (*b*), 48^{mm} (*c*). Several measured over 80^{mm} in length, and one fragment of a large crystal measured 55^{mm} on one face, and may have measured originally over 70^{mm} on the prism. Some crystals are very small, being 1^{mm} in diameter. The specific gravity was as follows: of No. 1, 3·2, of No. 2, 3·4. The hardness on the side of the prism is from 6 to 6·5, on the *O* plane about 7·5.

The crystals consist of a simple orthorhombic prism with the *O* plane largely developed; the other faces have not been fully determined as yet, but are possibly $1\text{-}\breve{i}$ and $1\text{-}\bar{i}$. They occur in a quartzyte vein in a mica schist of a brown color, scattered through which are beautiful small crystals of pyrrhotite. These which I exhibit and a few fragments are all that have been found as yet in the locality. A hasty visit to the place failed to bring to light any more specimens, the rock having been thrown into the excavation and all traces of the mineral thus obliterated. More attention paid to this locality would probably repay the mineralogist with a good reward.

Art. XXXVI.—*On the White Garnet form Wakefield, Canada;* by George F. Kunz.

[Read before the American Association for the Advancement of Science, at the Minneapolis Meeting, August, 1883.]

At McBride's, Lot 7, Range 1, Township of Wakefield, 21 miles north of Hull on the right bank of the Gatineau River, Canada, there have been found some remarkable white garnets. This occurrence has been known to a number of collectors for some years, but as yet little information regarding it has been published. On visiting the locality I found that the garnets occur in a vein from several inches to over one foot in width in the crystalline magnesian limestone, and I traced the vein east and west a distance of over 75 feet. This vein has been followed to the depth of more than six feet. The crystals vary in size from 1^{mm} to 80^{mm} in diameter and in color from colorless to yellow and brown; some of them are transparent enough to yield small gems. The brown color is very often the result of the oxidation of the associated pyrrhotite. The form is that of a dodecahedron, either alone or modified by the trapezohedron 2-2.

Associated with the garnet are crystals of pyrrhotite and fine crystals of a white pyroxene, the adhering crystals being held together sufficiently by the pyroxene to form fine groups of this mineral when the limestone has been removed by acid. Perfect isolated crystals are very uncommon. Determinations of the specific gravity of the mineral gave 3·6002 and 3·5948; of the Orford garnet 3·52 and 3·53. An analysis of the garnet by C. Bullman, Ph.B., yielded the following results:

Silica	38·80
Alumina	22·66
Sesquioxide of iron	1·75
Oxide of manganese	·3
Lime	35·
Magnesia	·68
	99·19

The spectroscope gave no potassium lines, soda was not determined.

An analysis of white garnet from Orford, Canada, by T. Sterry Hunt (see Geological Survey of Canada, p. 496), gave

SiO_2	Al_2O_3	CaO	MgO	FeO, MnO	Na_2O, K_2O	ign
38·60	22·71	34·83	0·49	1·60	0·47	1·10=99·80

ART. XXXVII.—*Horizontal Motions of small Floating Bodies in relation to the Validity of the Postulates of the Theory of Capillarity;* by JOHN LECONTE.

THAT my attempt to refer the phenomena of the horizontal motions of small floating bodies under the action of capillary forces, "exclusively to the elastic reactions of the tense surface film, whose form is modified by the proximity of the partly immersed solid bodies,"* should not have commanded the assent of many physicists, was to have been expected. The imperfections and shortcomings of my explanation of this class of phenomena in relation to the accepted theory of capillarity, as pointed out in the articles of Mr. J. T. Riley and Mr. A. M. Worthington,† served to fix my attention on the difficulties and ambiguities which invest one of the most obscure and unsatisfactory points in molecular mechanics. The still more recent discussions of Laplace's "Theory of Capillarity" by Lord Rayleigh and by Mr. Worthington,‡ afford glaring illustrations of the perplexities which environ the mathematical theory of this class of phenomena.

A more careful and somewhat prolonged consideration of these difficulties has led me to question the *validity* of one or more of the *fundamental postulates* of the generally accepted physical theory of capillarity, and to seek for a solution of some of these perplexities in the erroneous assumptions.

These *postulates*, as enunciated by the late Prof. J. Clerk-Maxwell (*Encyc. Britannica*, ninth edition, Article "Capillary Action"), may be stated as follows:

1. "For any given liquid surface, as the surface which separates water from air, or oil from water, the surface-tension is the same at every point of the surface and in every direction. It is also practically independent of the curvature of the surface, although it appears from the mathematical theory that there is a slight increase of tension where the mean curvature of the surface is concave, and a slight diminution where it is convex. The amount of this increase and diminution is too small to be directly measured." Moreover, tense liquid films "act like a sheet of india-rubber when extended, both in length and breadth, that is, it must exert surface-tension. The tension of the sheet of india-rubber, however, depends on the extent to which it is stretched, and may be different in different directions; whereas, the tension of the surface of a liquid remains the

* This Journal, III, vol. xxiv, pp. 416–425, December, 1882. Also Phil. Mag., V, vol. xv, pp. 47–56, January, 1883.

† Phil. Mag., for March, 1883, p. 191 et p. 198.

‡ Phil. Mag., for October and November, 1883, p. 309 et p. 339.

same however much the film is extended, and the tension at any point is the same in all directions."

2. It is generally assumed that Young's law of the constancy of the angle of contact between the surface of any given liquid and a given solid, obtains under the same conditions of cleanness and of temperature; and notably in all cases in which the surface of the solid has been well wetted with the liquid.

These constitute the *essential postulates*, so far as the mathematical theory relates to the *surface-tension* of liquid films as the physical cause of capillary phenomena. And to this aspect of the subject our attention will be restricted.

The admirable mathematical researches of Laplace in relation to this intricate problem in molecular mechanics, confirmed as they were, in all essential features, by the more refined analytical investigations by Gauss, of Poisson, and of Hagen, seemed to have long satisfied physicists that the mathematical theory of capillarity fully accounted for all the observed phenomena. The discrepancies between theory and experiment brought prominently to notice by the careful experiments of M. Simon (of Metz),* confirmed as they have been by the experimental researches of Bède,—do not seem to have disturbed confidence in the essential validity of the fundamental principles of the physical theory. And the still more glaring inconsistencies of the theory, revealed in the remarkable posthumous memoir of M. G. Wertheim,† do not seem to have attracted the attention which they deserve. The results obtained by the last mentioned experimenter, Prof. J. P. Nichol‡ regards as invalidating the basis of the mathematical theory, and he maintains that the whole subject needs to be re-investigated under a fuller and wider view of the conditions of the physical problem.

Indeed, it is very evident, that notwithstanding the classical researches of Laplace, Gauss and Poisson, and the more recent investigations of Dupré and Maxwell, the mathematical theory of capillarity presents difficulties which have not yet been fully surmounted. In common with many other problems in molecular physics, we here encounter difficulties and uncertainties originating in the different physical interpretations of the mathematical processes and their results. They involve the consideration of the true signification of mathematical results which are known to have been reached by processes which are *not rigorously exact.* Many of the differential equations are utterly unmanageable and incapable of integration unless certain *assumptions* are made. Hence questions arise in relation

* Ann. de Chim. et de Phys., III, vol. xxxii, pp. 5–41, 1851.
† Ann. de Chim. et de Phys., III, vol. lxiii, pp. 129–201, 1861.
‡ Cyc. of the Physical Sciences, Article "Capillarity," Third Edition, 1868.

to the warrantableness of such assumptions in particular cases. In short, we plunge into the quicksands of partial differential equations, of discontinuous functions and of integrals containing arbitrary functions, the arbitrariness of which has a signification in the applications of the functions to physical questions.

In the mathematical theory of capillarity, the integration of the fundamental differential equations is only capable of being effected in certain particular cases, so that experimental verification has been confined within very narrow limits. Beyond these restricted boundaries we are virtually deprived of the assistance of those wonder-working mathematical symbols whose brief logic speaks so convincingly to the human intellect. For, it must be borne in mind, that in problems of this character, no deduction from analysis is worthy of confidence which does not admit of a rational physical interpretation, capable of being tested by observation or experiment.

Restricting myself to the consideration of the physical cause of the horizontal motions of small floating bodies when brought near to one another, it is evident that if the surface tension is precisely the same in all parts of the liquid surface and is not at all modified by the formation of the adjacent meniscuses,—and further, if the angle of contact of the liquid with the solid remains constant—the horizontal as well as the vertical component of the elastic reaction of the intervening tense film must be independent of its radius of curvature. Now, the question is, are these two conditions or postulates realized in the class of phenomena under consideration? Some physicists have thought it possible that the angle of contact might vary with the curvature of the film adjacent to the wall of the solid; but the invariability of this angle, at least in the case of liquids which wet the surfaces of the solids,—seems to be generally admitted, as verified by numerous experiments, provided the temperature remains the same.

But the postulate that, at a given temperature, the surface-tension of a given liquid film is independent of the radius of curvature, is by no means certain. On the contrary, there are a number of capillary phenomena, which seem to point to a much more complete analogy between the reaction of a tense elastic film of liquid and that of an extended sheet of india-rubber, than is indicated by Prof. Maxwell in the postulate. Indeed, they seem to render it almost certain that, like the extended sheet of india rubber, the tension of the surface film of the liquid depends upon the extent to which it is stretched; and consequently, that when the film becomes, from any cause, sharply *curved*, the tension is really augmented.

In fact, the assumption of the constancy of the tension of liquid films at given temperatures, under all conditions of

extension and curvature, is evidently a mathematical deduction from Jurin's experimental law in relation to the elevation or depression of liquids in tubes and between parallel plates. Now, it is well known, that this law is very far from being experimentally verified for tubes of moderately large diameters and for parallel plates at considerable distances apart. In other terms, the constancy of the tension of liquid films is approximately verified by such experiments, only when the radius of curvature is very small.

Now, in the class of phenomena under consideration, the radii of curvature of the meniscuses are not very small. The movements of the floating bodies are observed to take place when they are more than two centimeters distant. The question of fact to be decided is, do the tensions of the external and internal meniscuses change with the alteration of the curvature of the united intervening meniscus due to the proximity of the partly immersed floating solids? If experiment answers this question in the affirmative, then the horizontal components of the tensile reaction of the exterior and interior meniscuses become unequal, notwithstanding the constancy of the angle of contact of the liquid film with the two sides of each of the floating solids: hence the bodies are urged in the direction of the greater horizontal component due to the change of tension.

Before submitting the experimental evidence in relation to this question, it is proper to indicate more definitely *how* the surface-tension of a liquid film is *measured*. This important capillary *constant*, usually designated by T, is defined by Maxwell,* "either as the surface energy per unit of area, or as the surface-tension per unit of contour, for the numerical values of these two quantities are equal." Hence in the case of a liquid surface in contact with the surface of a solid, the whole surface-tension at the line of contact of the liquid film is equal to T× length of contour in unit lengths.

Assuming the constancy of the angle of contact and the constancy of the surface-tension (T), it is easy to deduce Jurin's law for the elevation or depression of liquids in tubes and between parallel plates; and conversely, to find the numerical value of T, the assumed constant of surface-tension. Thus let

d = diameter of vertical tube,
and d' = distance between vertical parallel plates.

T = tension per unit-length of contour, for tubes,
and T′ = tension per unit-length of contour, for parallel plates.

a = angle of contact (constant), for tubes,
and a = angle of contact (constant), for parallel plates.

* "Encyc. Britannica," Ninth Ed., Article, "Capillary Action."

w = weight of unit-volume of liquid, for tubes,
and w = weight of unit-volume of liquid, for parallel plates.

h = mean height of meniscus above level, for tubes,
and h' = mean height of meniscus above level, for parallel plates.

Then for cylindrical tubes, the whole force exerted at the margin of the surface of the liquid in the interior $=\pi d \times T$; and its vertical component $= \pi d \times T \times \cos a$. This latter must be in equilibrium with the *weight* of the column of liquid elevated or depressed above or below the hydrostatic level. This weight $= \frac{\pi}{4} d^2 \times w \times h$. Hence, equating this force with the vertical component of the tension, we have $\frac{\pi}{4} d^2 \times w \times h = \pi d \times T \times \cos a$ $\therefore$ $h = \frac{4T \times \cos a}{d' \times w}$; which gives Jurin's law of inverse diameters. Similarly, for Parallel Plates, we have, $h' = \frac{2T' \times \cos a}{d' \times w}$. And, as according to the postulate, for any given liquid and solid, we must have $T = T'$, it follows from the above, that when $d = d'$, $h' = \frac{h}{2}$.

From the foregoing equations, expressions for the values of T and T′ can be readily deduced: Thus, we have,

$$T = \frac{h \times d \times w}{4 \cos a}, \text{ and } T' = \frac{h' \times d' \times w}{2 \cos a}.$$

In the case of water in a clean glass tube which has been well wetted with that liquid, the angle a is very generally assumed to be *zero*, that is to say, the interior wall of the tube is tangential to the marginal surface of the meniscus,—so that $\cos a = 1$. This assumption is in the highest degree *improbable*; for, in the case of all liquids which wet the surface of glass tubes, experiment shows, that the value of a depends upon *temperature*. It appears from the experiments of Brünner and of Wolf on the elevation of ether, bisulphide of carbon, oil of naphtha, and alcohol contained in strong capillary glass tubes; that when subjected to high temperatures, each of these liquids was observed to descend with the increase of temperature,—the meniscus becoming less and less concave, and at length the surface of the liquid in the tube becomes *horizontal*, or $a = 90°$. In such cases, doubtless, the value of T likewise undergoes a progressive diminution with augmentation of temperature. In view of the above-indicated experimental results, it is curious to witness the persistency with which the assumption is reitera-

ted by even the best physicists, that the value of a for water in a clean glass tube is *zero*.*

Moreover, even under ordinary conditions of temperature and pressure, the careful experiments of Quincke† prove, that at the temperature of 20° (C.), the actual angle of contact (a) of water with clean glass in the presence of air $=25°\ 32'$. However, this factor being constant for any given temperature, its absolute value does not alter the result so far as the experimental test is concerned. For any given liquid at a given temperature, if the postulate, that T or T′ is *invariable*, is true, we should have $\frac{h\times d\times w}{4\times\cos a}=\frac{h'\times d'\times w}{2\times\cos a}=$ Constant. Now, if h and h', and d and d' are measured in centimeters, in the case of water $w=1$ gram weight; so that the formulæ give the values of T and T′ in grams weight per centimeter of contour. Consequently, for water in contact with clean glass, we have

$$\text{T per centimeter of contour}=\frac{h\times d\times 1}{4\cos a}\text{ grams weight.}$$

$$\text{T′ per centimeter of contour}=\frac{h'\times d'\times 1}{2\cos a}\text{ grams weight.}$$

Now, according to this fundamental postulate of the capillary

* These changes in the values of T and a, due to the influence of *temperature*, are not inconsistent with the remarkable deductions announced by the great geometer Clairaut as early as 1743 (Théorie de la Figure de la Terre. Paris, 1808. pp. 105–128). To show this, let P=molecular attraction of the liquid for itself; p=molecular attraction of the solid for the liquid. Then, Clairaut indicated the following laws: (1) When $p=\frac{P}{2}$, the meniscus is horizontal; (2) When $p>\frac{P}{2}$, the meniscus is concave; (3) When $p<\frac{P}{2}$, the meniscus is convex. Now, in the case of water, alcohol, ether, etc., in contact with clean glass, at ordinary temperatures, $p>\frac{P}{2}$: and assuming that when the temperature augments, the attraction of the solid for the liquid (p) diminishes *faster* than the attraction of the liquid for itself (P); it is evident, that at a certain definite temperature, p must $=\frac{P}{2}$, and consequently, the meniscus becomes horizontal; and at a still *higher* temperature $p<\frac{P}{2}$, and the meniscus becomes convex. The experiments of Brünner and of Wolf have verified these deductions in the case of several liquids which wet glass. On the contrary, in the case of mercury in contact with glass, $p<\frac{P}{2}$; so that, when the temperature augments p becomes still *smaller*, the meniscus increases in convexity and the depression is *augmented*. This last result has been confirmed by the experiments of Frankenheim, who found the depression of mercury in glass tubes to be augmented by increase of temperature.

† Phil. Mag., IV, vol. xli, p. 265, (Table X), 1871. In a later memoir Quincke, (Phil. Mag., V, vol. v, p. 325, 1878,) found this angle (a)$=28°\ 48'$ for water in glass capillary tubes. His experiments show that the value of a depends on the *cleanness* of the glass; but it never became *zero*, except under extraordinary circumstances.

theory, these values should be the *same* for the same liquid at the same temperature; and moreover, these values ought to be the same for all variations of h and d, and h' and d' respectively. Finally, as this postulate depends upon the verification of Jurin's law, it follows that the products, $h \times d$ and $h' \times d'$ respectively ought to be *constant* for each pair of the factors; and also, that when $d=d'$, $h' \times d' = \frac{h \times d}{2}$.

These deductions of theory can, unfortunately, *only* be experimentally tested in the case of water in contact with clean glass. In order to make the comparison of the results of theory and experiment, I have computed the following table in which the values of d, h, d' and h' are furnished by the admirable experiments of M. Simon (of Metz).* The value of a is taken, in accordance with Quincke experiments, as $=25° 32'$; but inasmuch as this divisor is assumed to be *constant*, its *absolute* value is of no consequence in the comparison.

Water in Tubes.				Water between Parallel Plates.			
d in millimeters.	h in millimeters.	$h \times d$.	$T=\frac{h \times d}{4 \cos a}$ in grams. per centim. of contour.	d' in millimeters.	h' in millimeters.	$h' \times d'$.	$T'=\frac{h' \times d'}{2 \cos a}$ in grame. per centim. of contour.
25·300	0·019	0·481	0·0013	23·000	0.021	0·49	0·0027
18·000	0·200	3·600	0·0100	18·000	0·062	1·12	0·0062
14·000	0·440	6·160	0·0171	14·000	0·140	1·96	0·0109
8·600	1·510	12·986	0·0360	10·000	0·340	3·40	0·0188
5·400	3·650	19·710	0·0546	5·000	1·250	6·25	0·0346
2·200	12·800	28·160	0·0780	2·090	4·230	8·84	0·0490
1·250	24·000	30·000	0·0831	1·260	7·420	9·35	0·0518
0·570	55·600	31·692	0·0878	0·518	19·300	9·91	0·0549
0·360	89·000	32·040	0·0888	0·404	25·000	10·10	0·0560
0·140	233·000	32·620	0·0904	0·140	73·780	10·33	0·0572
0·050	663·000	33·150	0·0918				
0·025	1333·000	33·325	0·0923				
0·012	2884·000	34·608	0·0959				
0·0061	6828·000	41·651	0·1154				

A glance at the numbers contained in the foregoing table clearly indicates the following conclusions:

1. The numbers in the columns headed $d \times h$ and $d' \times' h$ show that Jurin's law fails to be even approximately verified, when d and d' respectively exceed 0·2 of a centimeter.

2. That when $d=d'$, $d' \times h'$ in all cases falls short of being equal to $\frac{d \times h}{2}$; the ratio of the products, under these condi-

* Ann. de Chim. et de Phys., III, vol. xxxii, pp. 12 et 19, (1851.)

tions, instead of being as 1 to 2, as the theory demands, is more nearly as 1 to π, as pointed out by Simon.

3. The numbers in the columns of T and T′ show that if the angle of contact remains the same, the computed values of the surface-tensions in the cases of tubes and parallel plates, are not constant under variations of d and d' respectively; in fact, they do not even approach constancy until d and d' become respectively less than 0·2 of a centimeter. On the contrary, the values of T and T′ respectively augment with the diminution of d and d'. Thus, a change in the value of d from 1·8 to 1·4 centimeters increases T in the ratio of 100 to 171; and a similar change in d' augments the value of T′ in the ratio of 62 to 109. Again, a change in the value of d' from 1·0 to 0·5 centimeters, increases T′ from 0·0188 to 0·0346 grams per centimeter of contour.*

4. The same columns show, that instead of T being equal to T′ (as required by theory), the former, under the same values of d and d', always exceeds the latter in nearly the ratio of 1·6 to 1, or $\frac{\pi}{2}$ to 1.

In the light of these experimental results, it would almost seem that the somewhat ambiguous expression "superior tension" of the intervening meniscus used by me in my article on the "Apparent Attractions and Repulsions of small Floating Bodies"† (to which exceptions have been justly taken), is, after all, the declaration of a physical reality.

In applying these results of experiment to the explanation of the horizontal motions of small floating bodies, it must be borne in mind that the phenomena under consideration begin to manifest themselves when the bodies are at such distances from one another, that these alterations of surface-tension become comparatively large as their proximity increases. In other terms, we have seen that the value of the surface-tension instead of being constant under all conditions, as the theory of capillarity assumes, is, in reality, an inverse function of the radius of curvature of the meniscus; so that the elastic reaction of the tense liquid film acts unequally on the opposite sides of the floating bodies, and thus becomes the true physical cause of their motions.

Thus far I have considered the phenomena in question as due exclusively to the change in the surface-tension incident to the proximity of the floating solids; but it is evident that a

* The value of the assumed "capillary constant," T, for water given by Quincke 0·08253 grams per centimeter of contour, evidently corresponds to its value in a glass tube whose internal diameter is about 0·15 of a centimeter. In the C. G. S. system this is equivalent to $0{\cdot}08253 \times g = 80{\cdot}962$ dynes.

† This Journal, III, vol. xxiv, p. 421, December, 1882.

change in the magnitude of the angle of contact, would likewise produce similar results. It is, *à priori*, by no means improbable that, at the same temperature, there may be some change in this angle with a change in the radius of curvature of the meniscus; but inasmuch as such alterations in this angle could hardly have escaped observation, it seems more probable that the phenomena are due to the changes of surface-tension in portions of the film investing the floating masses.

It is highly desirable that similar comparisons of the results of theory and experiment should be extended to other liquids than water; in other words, Simon's experiments should be repeated with other liquids.

It is not my purpose to supplement my previous article by any further discussion of the difficulties and inconsistencies of the hydrostatic explanation of this class of phenomena:—like Prof. J. D. Everett, I find it difficult to "conceive of negative pressure existing in the interior of a liquid." In this paper I have endeavored to establish the reality of the inequality of the tensile reaction of the liquid film on the opposite sides of the floating bodies when they are brought near to one another. This principle obviously explains the motions in each of the three cases considered in my previous paper; while at the same time, it serves to connect these phenomena with the perplexing capillary movements due to the difference of the surface-tensions of different liquids or of the same liquid in different states, which have engaged the attention of Tomlinson, Van der Mensbrugghe and others. In both classes of phenomena, the motions are obviously due to modifications of the tensile reaction of the surface films in parts that are adjacent to one another.

Berkeley, California, January 15, 1884.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On the reduction of Gases to Normal Volume.*—In the ordinary methods of measuring gases, long and tedious calculations are required to reduce the results to normal volume. Kreusler has proposed an apparatus by which these reductions may be much facilitated. It consists of a U-tube, one of whose legs terminates in a funnel and the other in a pipette-like enlargement, this latter ending above in a capillary tube. The gas-vessel thus formed has a capacity of about 50 c.c. actual; but its capacity is called 100 units of volume, and a mark is made on the tube below the bulb, corresponding to this capacity. A graduation based on these units is continued downward as far as is necessary; to 120 in the author's

apparatus. Since the graduation permits a unit to be divided into tenths, each division corresponds to 0·001 of the normal volume of the instrument. The adjustment is made by filling the tube with mercury nearly to the 100 mark, and, as the measurement is generally made on moist gas, adding a layer of water of equal depth on each surface. A calculation is then made to determine the space which 100 units of volume of dry air at the normal temperature and pressure would occupy when moist and under the temperature and pressure shown by the thermometer and barometer at the time of the calculation; and the water meniscus is brought carefully to this exact reading on the scale of the instrument. The capillary tube above is then closed with wax; or after repeated experiments have proved the adjustment correct, it is closed by fusion of the glass. To use the apparatus, the mercury is brought to stand at the same height in both legs of the tube, and the level of the water meniscus is read off; call it v. Then for any volume V of a gas at the same temperature, the volume V_0 dry and at normal pressure is given by the proportion $v : 100 :: V : V_0$; whence $V_0 = V \frac{100}{v}$. By surrounding the bulb with water it may readily be brought to any required temperature. A second form of the apparatus, less exact but smaller and more portable, is described in the paper.—*Ber. Berl. Chem. Ges.*, xvii, 28, Jan., 1884. G. F. B.

2. *On the Influence exerted by the surrounding Gaseous Medium on the Production of Electricity by Induction-machines.*—Hempel has studied the effect which varying the gaseous atmosphere surrounding a Töpler machine exerts upon its production of electricity. For this purpose the axis of the machine was made vertical, passing air-tight through an iron table upon which a glass bell to contain the machine, was secured. The useless space in this bell was filled with paraffin. The quantity of electricity was measured by the number of discharges which took place in the air between the poles of the machine from a Leyden jar in circuit, for a given number of turns of the machine. When the machine was enclosed in hydrogen 850 rotations per minute gave 9 discharges from the jar, while in air this number of rotations gave 45 discharges. In carbon dioxide, 850 rotations gave 47 discharges, a portion of the gas being decomposed into carbon monoxide and ozone. With 400 rotations per minute, in air at the ordinary pressure, the machine gave 15 discharges of the jar; while when the pressure was increased to two atmospheres 32 discharges were obtained per minute. On lowering the pressure to half an atmosphere, the jar could not be charged. An attempt to surround the machine with petroleum—a substance of high insulating power—gave no result. The researches are still in progress.—*Ber. Berl. Chem. Ges.*, xvii, 145, Feb., 1884. G. F. B.

3. *On the method employed for cleaning the Liebig Statue.*—On the 6th of November, the marble statue of Liebig, in Maximilian Place, Munich, which had been erected only the previous

August, was found to be covered with black spots and streaks, some miscreant having attempted to disfigure it. At first the dark material was supposed to be only mud, and an attempt was made to wash it off. But finding this of no avail, a commission, consisting of Drs. MAX VON PETTENKOFER, ADOLF BAEYER, and CLEMENS ZIMMERMANN, was entrusted with the matter and empowered to examine the question chemically and devise a method for restoring the statue. On examination about 300 of these black spots, nearly all round and of the size of a hazel-nut, were counted upon the statue itself, fourteen being on the face. The granite base of the monument was similarly stained. On testing one of these spots, formed under one of the feet, the presence of manganese was proved. A streak on the bronze wreath attached to the granite base disappeared when treated with nitric acid, and the solution gave a precipitate with hydrogen chloride which was soluble in ammonia and darkened in the light; thus proving the presence of silver. It therefore appeared that the stains were produced by solutions of silver nitrate and potassium permanganate. Laboratory experiments were then made to devise a method of removing these stains, which penetrated some millimeters into the marble. The process finally determined on was to treat these stains first with yellow ammonium sulphide, in order to convert the silver and the manganese into sulphides, and then with potassium cyanide, in which these sulphides are soluble. Experiments in the laboratory proving satisfactory, the process was tried on the 20th of November, on two stains upon the hand of the statue. A paste was made of fine porcelain clay mixed with ammonium sulphide and applied to these spots, being renewed after 24 hours. The day after, this paste was removed, the stains washed with water and a second paste applied, made with clay and a concentrated solution of potassium cyanide. After four hours the stains appeared fainter; and on renewing the application, not the slightest trace of the stain was observable on the following day. The work was then carried forward uninterruptedly, and on the 13th of December the statue was completely restored to its original purity and beauty; a result confirmed by the authorities on the 22nd in a special announcement.—*Ber. Berl. Chem. Ges.*, xvii, 230, Feb. 1884. G. F. B.

4. *On the Combustion of the Diamond.*—Having obtained some exceptionally pure and white specimens of diamond, very free from ash, FRIEDEL has submitted them to combustion in a current of oxygen with a view of determining the atomic weight of carbon. The oxygen, prepared from a mixture of copper oxide and potassium chlorate, was passed over heated copper oxide, then through a Liebig potash bulb and a series of U-tubes containing pumice soaked in potash, caustic potash in sticks, pumice moistened with sulphuric acid and phosphoric oxide, the junctions being made without rubber. Bohemian tubes proving too soft at the temperature required, tubes of porcelain were used in the combustion, being heated by a Wiesnegg combustion furnace. The products of com-

bustion passed through two U-tubes containing pumice moistened with sulphuric acid and phosphoric oxide, then through a Liebig potash bulb and a tube with pumice moistened with potassium hydrate, then through a tube with solid potash, and finally through one containing phosphoric oxide. A precisely similar series of tubes was used as a tare. The diamonds were weighed in a platinum boat after heating to low redness. Two blank experiments having established the integrity of the apparatus, two combustions were undertaken. In the first 0·4705 gram of clear white Cape diamonds, in small crystals, were used, and gave 1·7208 grams carbon dioxide. Since the ash weighed 0·0007 gram, the carbon consumed weighed 0·4698 gram. Considering that of oxygen as 16, this gives 12·017 as the atomic weight of carbon. Since this weight of carbon should have given 1·7229 of carbon dioxide, there was a loss of 0·0021 gram. In the second combustion 0·8621 gram of diamond was used and 3·1577 grams of carbon dioxide was obtained. Subtracting the ash 0·0005, there remains for the weight of carbon, 0·8616 gram. This gives 12·007 for the atomic weight. Taking 12 for the atomic weight, the carbon burned should have yielded 3·1592 of CO_2; a loss of 0·0015 gram. The ash consisted of minute white flocks, yellowish in places and showing small black specks, some of which were attracted by the magnet. Others were transparent and acted on polarized light. Certain Brazil diamonds showed nebulous spots of a dark green color, which became brown at the temperature of boiling cadmium; proving that these diamonds were formed at a temperature lower than this.—*Bull. Soc. Ch.*, II, xli, 100, Feb., 1884. G. F. B.

5. *On the behavior of Carbon monoxide toward air and moist Phosphorus.*—The experiments of Remsen and Kaiser, tending to prove that carbon monoxide mixed with air is not oxidized when passed over moist phosphorus, having been questioned by Leeds and Baumann, the former chemists have repeated their experiments, using larger volumes of air and taking all the precau tions which further experience suggested. A blank experiment, in which air alone, carefully purified, was passed over moist phosphorus, having shown the production of carbon dioxide, the apparatus was reconstructed with the greatest care so as to exclude organic matter of every kind, the joints being all of ground glass. The air, contained in a gasometer of 30 liters capacity, was passed slowly, two or three bubbles per second, first through a red-hot tube of hard glass containing copper oxide, then through three wash bottles, the first two of which contained caustic soda and the last baryta water, and finally into a bell jar over mercury, within which floated a glass pan containing the phosphorus. From the bell jar the ozonized air passed through two wash bottles, the first containing distilled water and the second baryta water. This latter was protected from the air by a potash tube. The result was precisely the same. Ten liters of air caused a distinct turbidity, and twenty to thirty gave a precipitate. Hence the conclusion of the authors that the carbon dioxide obtained must have

come from carbon contained in the phosphorus used. Though this conclusion was directly established, the quantitative experiments were not satisfactory, owing to the difficulty of regulating the oxidation. Repeating the above experiment with carbon monoxide, no increased production of the dioxide could be detected.—*Ber. Berl. Chem. Ges.*, xvii, 83, Jan., 1884. G. F. B.

6. *On the Temperature obtained by Oxygen in a state of Ebullition, and on the Solidification of Nitrogen;* by M. S. Wrobleski. —Of all the gases formerly regarded as permanent, hydrogen alone showed no sign of liquefaction at the temperature of —136° C. Even when this gas is submitted, at the above temperature, to a pressure of 150 atmospheres, and the pressure is then suddenly removed, no mist is formed in the tube containing the gas. Evidently, in order to liquefy hydrogen, we must employ a lower temperature than the minimum obtainable by means of liquid ethylene allowed to boil in a vacuum. Of the gases which are more difficult to liquefy than ethylene, and which might be used for the production of a much more intense cold, oxygen appeared to me to be the most serviceable.

The conditions under which the liquefaction of oxygen takes place being already ascertained by my previous researches, it follows that this gas can, at the present time, be liquefied in considerable quantities with great ease. Numberless processes and apparatus are conceivable which would allow of this liquefaction being effected in such a manner that the commercial production of liquid oxygen, if I may so express myself, is only a question of material means at the service of the experimenter. Thus since the beginning of October I have used liquid oxygen as a refrigerating agent.

When liquefied in large quantity and allowed to evaporate briskly by the sudden removal of the pressure, oxygen does not solidify like carbonic acid, but it leaves a crystalline residue on the bottom of the vessel in which it was contained in the liquid state and upon the object to be cooled, plunged in the oxygen. I cannot say whether this residue is composed only of crystals of oxygen or whether it arises from possible impurities, since the oxygen which I use in these experiments is prepared from a mixture of potassium chlorate with manganese peroxide. This residue disappears as the temperature commences to rise. If the object to be cooled is contained in a glass tube, the thin layer of this opaque residue is often very troublesome to the observer.

Another circumstance, which renders it very difficult to employ liquid oxygen as a cold-producer, is the necessity of using closed apparatus capable of great resistance. Hitherto I have not been able to obtain oxygen in a stable liquid condition under the pressure of one atmosphere. I have had, in consequence, to place the objects to be cooled in the apparatus, which I fill with liquid oxygen, and I can only avail myself of the cold which the boiling oxygen produces at the moment when the pressure is removed. As these apparatus are in part constructed of glass, great inconvenience results owing to the constant danger of serious explosions.

After several accidents had occurred during these experiments, my assistants and myself, in order to obviate the danger, never worked without masks. But the greatest difficulty to contend with is the short duration of the ebullition of the oxygen, and consequently the too short duration of the cold.

I have attempted to measure the temperature which the boiling oxygen produces. For this purpose I have adopted a method of thermo-electric measurement which, in addition to being highly sensitive, allows us to record all the sudden changes of temperature of the medium. The indications of the apparatus employed have been compared with those of a hydrogen-thermometer between $+100°$ C. and $-130°$ C. The nature of the function connecting these indications admits of an extrapolation being made. Reserving the description of my method for a future communication, I give here *one hundred and eighty-six degrees below zero* ($-186°$ C.) as the first approximation to the temperature which is produced on the liberation from pressure of liquefied oxygen.

I have submitted nitrogen successfully to the action of this cold. This gas compressed, cooled in boiling oxygen, and then slightly released from pressure, solidifies and falls like snow in crystals of remarkable size.—*Comptes Rendus*, Dec. 31, 1883.—*Phil. Mag.*, Feb., 1884.

7. *Diary of a Magnetic Survey of a portion of the Dominion of Canada chiefly in the Northwestern Territories;* executed in the years 1842–44, by Lieut. Lefroy, R.A., now General Sir J. H. Lefroy, C.B., etc., with maps, 192 pp. 8vo. London, 1883. (Longmans, Green & Co.).—The magnetic observations made by Lieutenant Lefroy in the years 1842–44 have been, since their publication in Sabine's Contributions to Terrestrial Magnetism (Phil. Trans. 1846), the principal authority for the accepted positions of the isogonic, isoclinic and isodynamic lines over most of British America as well as for the position of the north magnetic pole. Their author has now performed an important service to this branch of physical science in presenting these observations in convenient form, and with all the fulness of personal explanation which future observers in the same region could ask for. The body of the volume consists of a diary of the series of observations made in the Northwest at 314 stations, extending west to the Peace River and north to Fort Good Hope on the Mackenzie. In addition, the preliminary observations made in Canada and the United States are also given. The discussion of the instruments employed, of the variation in the magnetic elements observed and of other points, adds interest and value to the volume. Four large maps give the positions of the magnetic lines for the same epoch over the region covered by Lieutenant Lefroy, in preparing which observations by Captain R. W. Haig, Captain T. E. L. Moore and some others have been included.

8. *Notes on Electricity and Magnetism*, designed as a companion to Silvanus P. Thompson's Elementary Lessons by J. B. Murdock. 139 pp. 16mo. New York, 1884. (Macmillan & Co.).—

Lieutenant Murdock gives in this little volume a series of class-room notes, supplementary to the excellent text book of Professor Thompson; they will be of material assistance to the many teachers who use and appreciate the value of the latter work.

9. *The Relative Proportions of the Steam Engine*, being a rational and practical discussion of the dimensions of every detail of the steam engine; by WILLIAM DENNIS MARKS. Second edition, revised and enlarged. 215 pp. Philadelphia, 1884 (J. B. Lippincott & Co.).—This volume by Professor Marks is an admirable one, useful alike to the student and to the practical engineer. In this new edition three additional lectures are given upon the following subjects: the limitation of the steam engine; the cheapest point of cut-off; the errors of the Zeuner valve-diagram.

10. *Ueber den Polabstand, den Inductions und Temperaturcoefficient eines Magnetes und über die Bestimmung von Trägheitsmomenten durch Bifilarsuspension.* — Messrs. W. HALLOCK and F. KOHLRAUSCH have recently contributed to the Society at Göttingen a brief account of some experiments undertaken to determine the polar distances of a magnet, the coefficient of induction and temperature, and the moment of inertia as given by the method of bifilar suspension. The complete memoir will be published later.

II. GEOLOGY AND NATURAL HISTORY.

1. *Paleontological similarity of the East-American Acadian and Potsdam groups.*—Mr. R. P. WHITFIELD, in a paper on new Primordial fossils, contained in the American Museum, of New York, published in Bulletin No. 5 of the Museum, expresses the opinion that the Potsdam sandstone is not yet proved to be of a different geological horizon from that of the other Atlantic Primordial areas, or of those of the Mississippi valley. The New Brunswick and Massachusetts localities afford the *Paradoxides* type of trilobite; but, he remarks, this is not necessarily a consequence of difference in time. Looking to the other fossils, the facies of the New Brunswick fauna is no older than that of the lower beds in Wisconsin, for the same type of *Conocephalites* occurs in each; and the Brachiopods, *Orthis Billingsi* and *Discina Acadica* (if a Brachiopod), are of newer type than any in the Wisconsin fauna. As to the *Discina*, he states that, according to a specimen received by him from Mr. Matthews, it is certainly not a *Discina*, and probably the fossil is the imprint of a univalve shell, either of the genus *Palæacmea* or *Stenotheca*; and Palæacmea is known from Wisconsin, and both of these genera from New York. Moreover, his *Orthisina orientalis*, described in the paper, from Georgia, Vermont, he says closely resembles and may be identical with the Wisconsin and Lake Pepin *Orthisina Pepina* of Hall.

2. *Soil-cap movements.*—In a paper read before the Royal Dublin Society in November, 1882, Professor V. Ball draws attention to the effects of land-slips or soil-cap movements in throwing

dams across valleys and making lakes, and refers to a case at Naina Tal in the Himalayas where a land-slip appears to have produced this result. He points out, also, that they make bowlder deposits resembling those of glacier origin, and sometimes cause a shallowing of channels and sea-borders which might be taken as evidence of an elevation of the land. He cites from a paper by Dr. Coppinger in the Quarterly Journal of the Geological Society of London (xxxvii, 245, 1881), about soil-cap slides over sloping surfaces of rock in western Patagonia, which carried along, besides trees and other plants of the surface, "a *moraine profonde*" of rocks, stones and trunks of trees, filling valleys and lakes, that, after a removal by water of the finer part, became a deposit of bowlders piled on one another, in true glacier-made style.

3. *Handbuch der Botanik*, von Professor Dr. N. J. C. Müller, Münden. 2 Bände (648, 482 pp.), 8vo. Heidelberg, 1880.

Pflanzenphysiologie. Ein Handbuch des Stoffwechsels und Kraftwechsels in der Pflanze, von Dr. W. Pfeffer, Professor an der Universität Tubingen. 2 Bände (383 u. 474 pp.), 8vo. Leipzig, Engelmann, 1881.

Vorlesungen über Pflanzenphysiologie, von Julius Sachs. (Professor an der Universität Würzburg), (991 pp.), 8vo. Leipzig, Engelmann, 1882.

Traité de Botanique, par Ph. Van Tieghem, Professeur au Muséum d'Histoire Naturelle (1656 pp.) 8vo. Paris, Librairie F. Savy. 1884.

Handbuch der Botanik, herausgegeben von Professor Dr. A. Schenk, unter mitwirkung, von Cohn, Detmer, Drude, Frank, Kienitz-Gerloff, Kraus, Müller (zu Lippstadt), Sadebeck, u. a. 8vo. Breslau, Trewendt. [Now publishing in parts which appear somewhat irregularly, as the first portion of an Encyclopedia of Natural History.]

These are the principal comprehensive works upon their respective subjects which have appeared within the last few years. A treatise upon Pharmaceutical and Medical Botany by Luerssen rivals these in size and in carefulness of management throughout, but cannot be described in detail in the present notice. Neither is it convenient to examine at present the newer text-books of smaller size, by Reinke, Wiesner and Baillon. They are merely mentioned in passing, to indicate that there is considerable activity on the continent, in the preparation of manuals for students of botany. Müller's Handbook is a remarkably difficult work both for the general and special reader. It has altogether too much mathematical physics in it for the former, and too little for the latter; that is, it stops just short of being what it could have been made under a different treatment. By a slight rearrangement of the copious material and with a few necessary additions, it would be a useful work of reference; by a complete removal of the unnecessary mathematics and some of the puzzling diagrams which are nowhere explained, it would be a stimulating handbook for a certain class of botanical students. But, as it

stands, it is the least useful text-book upon its subject: Grassmann's Pflanzenleben rivals it in obscurity, but does not approach it in the wealth of disarranged material.

Pfeffer's Vegetable Physiology is a masterly treatise. It presents in systematic form, and with references throughout, a synoptical exposé of nearly all that is known in regard to the functions of the organs of vegetation. The arrangement is convenient both for study and reference. The general statements are cast in the mould of a physicist and chemist rather than in that of a morphologist, and bear, for the most part, evidence of critical examination of the phenomena. For instance, when dealing with the subject of osmosis, the author views the whole matter in the light of his personal experiments, and yet does not throw any part of the theme out of proportion. Likewise in the management of assimilation and of movements, he is guided by his own observations, and therefore is all the more free to criticise the writings of others. It should be said, however, that his criticisms are fair and are generally expressed in a kindly manner. The first volume deals with the reception of inorganic matter by plants and their conversion of this into organic substance. The great topics of absorption and assimilation are treated with much detail, while the minor ones of transmission and transpiration of water receive almost as much attention. The formation of nitrogenous compounds within the plant, a subject to which Pfeffer has devoted much time, is treated pretty fully but is not left in a wholly satisfactory state, nor is the subject of respiration, especially that which is known as "intra-molecular," so extensively presented as it appears to deserve. In the second volume, the release of energy is discussed under growth, movement, and the production of light, heat and electricity. Nearly every page exhibits personal familiarity with the phenomena described and not merely with the literature. The propositions are everywhere well presented, but the arguments in support of them are not always as clearly put. Part of the fault comes no doubt from the unwillingness to place headings at the proper places in the statement and thus due proportions are not always preserved. As a trustworthy work of reference in the laboratory, as a guide which will seldom lead astray and never far from the right, the treatise is a thoroughly satisfactory contribution to vegetable physiology.

Professor Sachs has been repeatedly asked by his publishers to prepare a fifth edition of his text-book, but he felt so much unwillingness to undertake the revision, that a compromise was at last effected with which both he and the publishers may well be satisfied. The systematic portion is turned over to a most promising young professor who has recently established himself at Rostock, and the work has already appeared under Goebel's name and with Sachs's sanction. The rest of the text-book has been wholly recast, and is now published as a series of forty-six lectures. It may be said at the outset, that the lectures are in-

teresting in the extreme. They are characterized by felicity of expression and by the exclusion of unnecessary matters, so that from first to last the reader's interest is not permitted to flag. Their thoroughly attractive character ensures the early translation into other languages.

The first series comprises eleven lectures upon the histological and morphological characters of plants in general. All plant organs are placed in two categories, root and shoot. The former comprises that part of the plant which on or in a substratum serves as a hold fast, and in the latter case acts as an organ for conducting into the plant nutritive matters held in the substratum. The shoot (or the shoot-system) is that part which unfolding outside of the substratum produces plant-substance and serves for propagation, bearing organs of reproduction which are never seen on roots. That both fulfill their characteristic functions depends on their diverse reactions with the natural forces. To be sure, there are roots which *may* produce shoots, and shoots *do* give rise to roots; but this only shows that in the progressive development of the vegetable world, with progressive adaptation of the different organs to special conditions of life, individual characters disappear and new ones arise. According to this view no distinction is made between the rhizoids of a thallophyte and the root of a vascular plant. These new morphological categories cannot prove as satisfactory to students as those given in his text-book, root, stem, leaf, plant-hair. In the first eleven lectures the whole field of general histology and morphology is well covered. A second series, of two lectures only, treats of the most general conditions of plant life, such as temperature, light, habitat, etc., and the most general phenomena presented by a living plant, to wit: osmotic power, turgescence, tension of tissues, together with some explanation of the mechanics of a plant.

In the third series, Nutrition in the widest sense is dealt with in twelve lectures which range from absorption of liquids and gases, through assimilation and elaboration, to the final release of the products of respiration. In this series insectivorous plants are spoken of. The fourth series is the freshest in material and treatment. It takes up very fully the whole subject of the growth of the cell, formation of new cells non-sexually, and the increase in size of the whole plant. The newest researches are referred to and illustrated by good diagrams from many sources, some of the very best drawings now appearing for the first time. In the fifth series the movements of various kinds are treated of, in much the same manner as in the last edition of the text-book. The concluding series of six lectures takes up the principal kinds of sexual reproduction in a very general manner. Much of the matter in these lectures is speculative of course, and is not likely to be received without question. But all statements are clearly made, and the interdependence of the topics always kept in mind. The notes of reference at the end of each lecture must be meant as hints to Professor Sachs's own students, since they refer

very largely to work done either by him or in the Würzburg laboratory. The notes do not pretend to cover the literature of the subject.

To many American students of Botany, Professor Van Tieghem is known as a successful investigator of some difficult problems in histology and physiology, and for his work in the department of cryptogamic botany. But he is more widely known in this country as the editor of a French translation of Sachs's Text-book. It will be remembered that many of the very long paragraphs of the original were broken up in the translation into shorter ones with appropriate headings, often embodying in a few words the gist of what followed. In the volume now before us the author has adopted the same plan. If it were not for this convenient method of reference the work would be far from attractive; but with it, its encyclopedic character is more or less masked. Moreover, a substantial gain has been made for the general reader by suppressing, as far as possible, references in the text to the sources of the author's information. Hence the story is, so to speak, continuous. At the beginning of the great divisions, copious references to the literature are given, and occasionally they are noted in the text. The work is divided into a general and a special part. The first book of the former is devoted to a study of the external form of the adult plant and of the phenomena which are exhibited in this state. Division of labor; and kindred subjects are treated in a general manner, and then follows a particular examination of root, stem, leaf and flower, the chapter given to each of these organs being divided into two parts, Morphology and Physiology. It is obvious that this arrangement leads sometimes to repetition which may be tedious; or, when there is too marked an effort to avoid repetition, some facts may be overlooked. The second book treats of internal morphology and the physiology of the cell and of special tissues; the third traces the development of the plant from its youngest state to its adult form. In the latter, a very general view is taken of the whole vegetable world, and cryptogams receive their proportional share of attention. This book closes with a study of close fertilization, cross-fertilization and hybridization, and with some discussion of the origin of species. Of the latter, the author says: "It (the theory of descent) explains in a simple and satisfying manner why living plants are so well armed for their conflict, why identical members are adapted to the most diverse uses, why there are rudimentary organs, how plants have succeeded each other on the surface of the globe at different geological epochs, etc., etc., all of which problems would remain unsolved without it." "But if we wish to preserve to this theory its scientific value we must deduce our conclusions with prudence and control them by direct observation and by the experimental method."

The second part of the work is devoted to a special study of the orders of lower and of higher plants. The arrangement is

novel in some particulars, although not now calling for remark. The work closes with a consideration of the paleontological and geographical relations of plants. Thus it will be seen that the treatise is a general work of wide range. It is characterized from beginning to end by qualities which give it a high value for teachers of botany and for advanced students, namely great clearness of statement, and an emphasis of important points. It is to be regretted that more prominence has not been given by the author to some of the recent German works in a few of the subjects treated, especially as the works are themselves cited by him. But it must be said that these cases of omission are comparatively few and do not seriously impair the value of the excellent treatise.

The encyclopedic handbook now in course of publication under the editorship of Professor Schenk, promises to be a valuable collection of morphological, histological and physiological monographs. Of course, in a work prepared by many hands, the repetitions are numerous and there is much waste of energy. On the other hand, we are given several views of the same subject and this may lead to a clearer conception of matters in doubt. The most noteworthy papers thus far at hand are the following: Mutual relations of flowers and insects (with regard to crossing) by H. Müller, Vascular cryptogams by Sadebeck, Diseases of Plants by Frank, Morphology of Phanerogams by Drude, Physiology by Detmer, Algæ by Falkenberg, Physiological adaptations of tissues by Haberlandt, and Comparative development of the Organs of Plants by Goebel. There does not appear to be any "editing" in the true sense of the word, if indeed any such thing were possible with so diverse contributions. The accumulation of material ready for coördination is however very great and the work will be an abundant source to which teachers will go for illustration. Special monographs may be noticed in a future number. G. L. G.

4. *Tendency in Variation.* — In the review in this Journal of Darwin's Origin of Species, which appeared very shortly after the publication of that "epoch-making" work, the writer intimated that there was reason to believe "that variation has been led along certain beneficial lines, like a stream 'along definite and useful lines of irrigation.'" Mr. Darwin devoted the closing page of his next work to this suggestion, and argued that, under his view of the case, plan should be superfluous. It may be doubted if he ever convinced himself that it was so, although he has convinced a host of his followers, who, as often happens, were more facile believers than their master. A good many years have passed; and now, wherever we turn from the speculators to the investigators who have been working upon the problem of descent with variation, we meet with this idea of definite tendency. The suggestion, and the need of it, are well brought out by that veteran investigator of the Foraminifera, Dr. Carpenter, in his recent paper in the

Philosophical Transactions (part ii, 1883), *On an Abyssal Type of the Genus Orbitolites; a Study in the Theory of Descent*,—the closing portion of which is here reproduced.

"I propose, in the last place, briefly to examine the bearing of the remarkable case of 'descent with modification,' which I have thus detailed, upon the general 'Theory of Descent' and of the 'Origin of Species.'

"Those who find in 'natural selection' or the 'survival of the fittest' an all-sufficient explanation of the 'origin of species,' seem to have entirely forgotten that before 'natural selection' can operate, there must be a range of varietal forms to select from; and that the fundamental question is (as Mr. Darwin himself clearly saw, at any rate in his later years), *what gives rise to variations?* No exercise of 'natural selection' could *produce* the successive changes presented in the evolutionary history of the typical *Orbitolites*, from *Cornospira* to *Spiroloculina*, from *Spiroloculina* to *Peneroplis*, from *Peneroplis* to *Orbiculina*, from *Orbiculina* to the 'simple' forms of *Orbitolites*, and from the 'simple' to the 'complex' forms of the last-named type. And as all these earlier forms still flourish under conditions which (so far as can be ascertained) are precisely the same, there is no ground to believe that any one of them is better fitted to survive than another. They all imbibe their nourishment in the same mode; and no one type has more power of going in search of it than another. That they are all dependent on essentially the same conditions of temperature and depth of water, is shown by their occurrence in the same marine areas. That they all equally serve as food to larger marine animals, can scarcely be doubted; and it is hardly conceivable that any of their devourers would discriminate (for example) between the disks of a large *O. marginalis*, a middle-sized *O. duplex* and a small *O. complanata*, which even the trained eye of the naturalist cannot distinguish without the assistance of a magnifying-glass.

"To me, therefore, it appears that the doctrine of 'natural selection' can give no account of either the origin or the perpetuation of those several types of Foraminiferal structure which form the ascending series that culminates in *Orbitolites complanata*. On the other hand, there seems traceable throughout that series a *plan* so definite and obvious, as to exclude the notion of 'casual' or 'aimless' variation. Between the simple spirally-coiled sarcodic cord of a young *Cornuspira*, and the discoidal body of an *Orbitolite*, with its thousands of sub-segments disposed with the most perfect symmetry, and connected together in most regular and uniform modes, who (in the absence of the intervening links) would have suspected any genetic relation—who would have ventured to construct a pedigree? And yet we find the gradations from the one to the other to be not only most complete, but often significant of further progress; many of the changes being such as seem to have no meaning except as anticipations of greater changes to come. Thus, the slight constrictions that show them-

selves in the first spiral coil of *O. tenuissima* are what constitute the essential difference between the spire of *Cornuspira* and that of *Spiroloculina*; marking an imperfect septal division of the spire into chambers, which cannot be conceived to affect in any way the physiological condition of the contained animal, but which foreshadows the complete septal division that marks the assumption of the Peneropline stage. Again, the incipient widening-out of the body, previously to the formation of the first complete septum, prepares the way for that great lateral extension which characterizes the next or Orbiculine stage; this extension being obviously related, on the one hand, to the division of the chamber-segments of the body into chamberletted sub-segments, and, on the other, to the extension of the zonal chambers round the 'nucleus,' so as to complete them into annuli, from which all subsequent increase shall take place on the cyclical plan.

"In *O. marginalis*, the first spiral stage is abbreviated by the drawing-together (as it were) of the 'spiroloculine' coil into a single Milioline turn of greater thickness; but the Orbiculine or second spiral stage is fully retained. In *O. duplex*, the abbreviated Milioline center is still retained, but the succeeding Orbiculine spiral is almost entirely dropped out, quickly giving place to the cyclical plan. And in the typical *O. complanata* the Milioline center is immediately surrounded by a complete annulus, so that nothing remains of the original spire save the one turn of the circumambient segment. So, in the passage from the 'simple' to the 'complex' type, we have a remarkable anticipatory step in *O. duplex*, which can scarcely be supposed itself to derive any advantage from the substitution of a double for a single row of communications between the annuli, since *O. marginalis* flourishes equally well with its single row; but which forms, so to speak, a stepping-stone to a higher grade.

"Everything in this history, then, shows *a well-marked progressive tendency along a definite line towards a highly specialized type of structure in the Calcareous fabric;* and this without any corresponding departure from the original homogeneity of the animal body which forms that fabric. And as being, so far as I know, altogether unique in these peculiarities, I venture to offer this study of a humble protoplasmic organism, brought up from an ocean-depth of nearly two miles, to the consideration of those who believe, with Sir James Paget, that the highest laws of our [biological] science are expressed in the simplest terms in the lives of the lowest orders of Creation."

APPENDIX.

ART. XXXVIII.—*Principal Characters of American Jurassic Dinosaurs;* by Professor O. C. MARSH. Part VIII. *The Order Theropoda.* (With Plates VIII–XIV.)

THE carnivorous *Dinosauria* form a well marked order, which the writer has called the *Theropoda*, in his classification of this group.* Although much has been written about these reptiles since Buckland described *Megalosaurus* in 1824, but little has really been made out in regard to the structure of the skull, and many portions of the skeleton still remain to be determined.

The fortunate discovery of two nearly perfect skeletons of this order, as well as a number of others with various important parts of the skeleton in good preservation, has afforded the writer an opportunity to investigate the group, and some of the results are here presented. A more detailed description of these fossils, and others allied to them, will be given in another communication.

Of the carnivorous Dinosaurs from the American Jurassic, there are four genera, which each represents, apparently, a distinct family. These genera are *Allosaurus*, *Cœlurus*, *Labrosaurus*, and the new genus *Ceratosaurus*, here described. In the present article, *Allosaurus* and *Ceratosaurus* will be mainly used to illustrate the more important characters of the order, and the relations of the other genera to them will be indicated in the classification presented in conclusion.

* This Journal, vol. xxiii, p. 81, January, 1882. See also vol. xxi, p. 423, May, 1881; p. 339, April, 1881; and vol. xvii, p. 89, January, 1879.

The specimen of *Ceratosaurus* here first described presents several characters not hitherto seen in the *Dinosauria*. One of these is a large horn on the skull; another is a new type of vertebra, as strange as it is unexpected; and a third is seen in the pelvis, which has the bones all coössified, as in existing Birds. *Archæopteryx* alone among adult birds has the pelvic bones separate, and this specimen of *Ceratosaurus* is the first Dinosaur found with all the pelvic bones anchylosed. Another feature of this skeleton, not before seen in the *Theropoda*, is the presence of osseous dermal plates. These extend from the base of the skull along the neck, over the vertebræ. The plates appear to be ossified cartilage.

This interesting fossil is quite distinct from any hitherto described, and, as it represents a new genus and species, may be called *Ceratosaurus nasicornis*. It also belongs to a new family, which may be named the *Ceratosauridæ*.

The skeleton, which is almost perfect, is over seventeen feet in length by actual measurement. The animal when alive was about half the bulk of the species named by the writer *Allosaurus fragilis*, which is from the same geological horizon. A second skeleton, some parts of which, also, are here described, is referred to the latter species.

The Skull.

The skull of *Ceratosaurus nasicornis* is very large, in proportion to the rest of the skeleton. The posterior region is elevated, and moderately expanded transversely. The facial portion is elongate, and tapers gradually to the muzzle. Seen from above, the skull resembles in general outline that of a crocodile. The nasal openings are separate, and lateral, and are placed near the end of the snout, as shown in Plate VIII.

Seen from the side, this skull appears Lacertilian in type, the general structure being light and open. From this point of view, one special feature of the skull is the large, elevated, trenchant horn-core, situated on the nasals (Plate VIII, fig. 1, *b*). Another feature is the large openings on the side of the skull, four in number. The first of these is the anterior nasal orifice (*a*); the second, the very large triangular antorbital foramen (*c*); the third, the large oval orbit (*d*); and the fourth, the still larger lower temporal opening (*e*). A fifth aperture, shown in the top view of the skull (Plate VIII, figure 3, *h*), is the supra-temporal fossa. These openings are all characteristic of the *Theropoda*, and are found also in the *Sauropoda*, but the antorbital foramen is not known in any of the other *Dinosauria*.

The plane of the occiput, as bounded laterally by the quadrates, is inclined forward. The quadrates are strongly inclined backward, thus forming a marked contrast to the corresponding bones in *Diplodocus*, and the other *Sauropoda*. The occipital condyle is hemispherical in general form, and is somewhat inclined backward, making a slight angle with the long axis of the skull. The basi-occipital processes are short, and stout. The par-occipital processes are elongate and flattened, and but little expanded at their extremities. They extend outward and downward, to join the head of the quadrate.

The hyoid bones appear to be four in number. They are elongate, rod-like bones, somewhat curved, and in the present specimen were found near their original position.

The parietal bones are of moderate size, and there is no parietal foramen. The median suture between the parietals is obliterated, but that between these bones and the frontals is distinct.

The frontal bones are of moderate length, and are closely united on the median line, the suture being obliterated. Their union with the nasals is apparent on close inspection.

The nasal bones are more elongate than the frontals, and the suture uniting the two moieties is obsolete. These bones support entirely the large compressed, elevated horn-core, on the median line. The lateral surface of this elevation is very rugose, and furrowed with vascular grooves. It evidently supported a high, trenchant horn, which must have formed a most powerful weapon for offense and defense. No similar weapon is known in any of the *Dinosauria*, but it is not yet certain whether this feature pertained to all the members of this family, or was only a generic character.*

The premaxillaries are separate, and each contained only three functional teeth. In the genera *Compsognathus* and *Megalosaurus*, of this order, each premaxillary contained four teeth, the same number found in the *Sauropoda*. In the genus *Creosaurus*, from the American Jurassic, the premaxillaries each contain five teeth, as shown in Plate IX, figure 3.

The maxillary bones in the present specimen are large and massive, as shown in Plate VIII, figure 1. They unite, in front, with the premaxillaries by an open suture; with the nasals, laterally, by a close union; and, with the jugal behind, by squamosal suture. The maxillaries are provided each with fifteen functional teeth, which are large, powerful, and

* The "horn" of *Iguanodon* described by Mantell, and since regarded as a carpal spine, proves to be the distal phalange of the thumb.

trenchant, indicating clearly the ferocious character of the animal when alive. These teeth have the same general form as those of *Megalosaurus*, and the dental succession appears to be quite the same.

Above the antorbital foramen on either side, is a high elevation composed of the prefrontal bones. These protuberances would be of service in protecting the orbit, which they partially overhang.

The orbit is of moderate size, oval in outline, with the apex below. It is bounded in front by the lachrymal, above this by the pre-frontal, and at the summit the frontal forms for a short distance the orbital border. The post-frontal bounds the orbit behind, but below, the jugal completes the outline.

The jugal bone is ⊥-shaped, the upper branch joining the post-frontal, the anterior branch uniting with the lachrymal, above, and the maxillary below. The posterior branch passes beneath the quadrato-jugal, and with that bone completes the lower temporal arch, which is present in all known Dinosaurs.

The quadrato-jugal is an ⊥-shaped bone, and its anterior branch is united with the jugal by a close suture. The vertical branch is closely joined to the outer face of the quadrate.

The quadrate is very long, and compressed antero-posteriorly. The head is of moderate size, and is enclosed in the squamosal. The lower extremity of the quadrate has a double articular face, as in some birds. One peculiar feature of the quadrate is a strong hook, on the upper half of the outer surface. Into this hook of the quadrate, a peculiar process of the quadrato-jugal is inserted, as shown in Plate VIII, figure 1.

The pterygoid bones are very large, and extend well forward. The posterior extremity is applied closely to the inner side of the quadrate. The middle part forms a pocket, into which the lower extremity of the basi-pterygoid process is inserted. To the lower margin of the pterygoid is united the strong, curved, transverse bone, which projects downward below the border of the upper jaws, as shown in Plate VIII, figure 1, *t*.

There is a very short, thin columella, which below is closely united to the pterygoid by suture, and above fits into a small depression of the post-frontal.

The palatine bones are well developed and, after joining the pterygoids, extend forward to the union with the vomers. The latter are apparently of moderate size.

The pre-sphenoid is well developed, and has a long pointed anterior extremity.

The whole palate is remarkably open, and the principal bones composing it stand nearly vertical, as in the *Sauropoda*.

The Brain.

The brain in *Ceratosaurus* was of medium size, but comparatively much larger than in the herbivorous Dinosaurs. It was quite elongate, and situated somewhat obliquely in the cranium, the posterior end being inclined downward. The position of the brain in the skull, and its relative size, is shown in Plate IX, figure 1. A side view of the brain-cast is shown in the same plate, figure 2.

The foramen magnum is small. The cerebellum was of moderate size. The optic lobes were well developed, and proportionally larger than the hemispheres. The olfactory lobes were large, and expanded. The pituitary body appears to have been very large.

The Lower Jaws.

The lower jaws of *Ceratosaurus* are large and powerful, especially in the posterior part. In front, the rami are much compressed, and they were joined together by cartilage only, as in all Dinosaurs. There is a large foramen in the jaw, similar to that in the crocodile, as shown in Plate VIII, figure 1, *f*. The dentary bone extends back to the middle of this foramen. The splenial is large, extending from the foramen forward to the symphysial surface, and forming in this region a border to the upper margin of the dentary. There were fifteen teeth in each ramus, similar in form to those of the upper jaws.

A peculiar dentary bone, recently found, and here referred to *Labrosaurus*, is shown on Plate IX, figure 4. It is edentulous in front, and the posterior portion is much decurved. The teeth are more triangular than in the other genera of this order. The species it represents may be called *Labrosaurus ferox*.

The Vertebræ.

The cervical vertebræ of *Ceratosaurus* differ in type from those in any other known Reptiles. With the exception of the atlas, which is figured in Plate X, all are strongly opisthocœlian, the cup on the posterior end of each centrum being unusually deep. In place of an equally developed ball on the anterior end, there is a perfectly flat surface. The size of the latter is such that it can only be inserted a short distance in the adjoining cup, and this distance is accurately marked on the centrum by a narrow articular border, just back of the flat anterior face. This peculiar articulation leaves more than three-fourths of the cup unoccupied by the succeeding

vertebra, forming, apparently, a weak joint. This feature is shown in Plate X, figures 2, 3, and 4.

The discovery of this new form of vertebra shows that the terms opisthocœlian and procœlian, in general use to describe the centra of vertebræ, are inadequate, since they relate to one end only, the other being supposed to correspond in form. The terms convexo-concave, concavo-convex, plano-concave, etc., would be more accurate, and equally euphonious.

In *Ceratosaurus*, as in all the *Theropoda*, except *Cœlurus*, the cervical ribs are articulated to the centra, not coössified with them, as in the *Sauropoda*. The latter order stands almost alone among Dinosaurs in this respect, as both the *Stegosauria* and the *Ornithopoda* have free ribs in the cervical region.

The dorsal and lumbar vertebræ are bi-concave, with only moderate concavities. The sides and lower surface of the centra are deeply excavated, except at the ends, as shown in Plate X, figure 5. These vertebræ show the diplosphenal articulation seen in *Megalosaurus*, and also in *Creosaurus*, as shown in Plate XIV, figure 3.

All the pre-sacral vertebræ are very hollow, and this is also true of the anterior caudals.

There are five well coössified vertebræ in the sacrum in the present specimen of *Ceratosaurus nasicornis*. The transverse processes are very short, each supported by two vertebræ, and they do not meet at their distal ends.

In the type specimen of *Creosaurus*, there are only two sacral vertebræ coössified. In *Megalosaurus*, there are five, and the number appears to vary in different genera of the *Theropoda*, as it does in the *Sauropoda*.

The caudal vertebræ are bi-concave. All the anterior caudals, except the first, supported very long chevrons, indicating a high, thin tail, well adapted to swimming. The tail was quite long, and the distal caudals were very short.

The Fore Limbs.

The fore limbs in *Allosaurus*, and in fact in all known *Theropoda*, were very small. The scapula and coracoid resembled those of *Megalosaurus*. The humerus was short, and somewhat sigmoid in form. The shaft was hollow, as in all the limb bones of this genus. The manus was peculiar in having some of its digits armed with powerful compressed claws, which formed most effective weapons. These claws, in some allied forms, have been referred to the hind feet, but the latter, in all the known *Theropoda*, have their claws round, and not compressed. The fore limb of *Allosaurus fragilis* is shown on Plate XII.

The Pelvic Arch.

The pelvic bones in the *Theropoda* have been more generally misunderstood than any other portion of the skeleton in Dinosaurs. The ilia, long considered coracoids, have been since usually reversed in position; the ischia have been regarded as pubes; while the pubes themselves have not been considered as part of the pelvic arch.

Fortunately, in the present specimen of *Ceratosaurus*, the ilium, ischium, and pubes are firmly coössified, so that their identification and relative positions cannot be called in question. The ilia, moreover, were attached to the sacrum, which was in its natural place in the skeleton, and the latter was found nearly in the position in which the animal died. The pelves of *Ceratosaurus* and of *Allosaurus* are shown in Plate XI.

The ilium in *Ceratosaurus* has the same general form as in *Megalosaurus*. In most of the other *Theropoda*, also, this bone has essentially the same shape, and this type may be regarded as characteristic of the order. In *Creosaurus*, the anterior wing is more elevated, and the emargination below it wider, as shown in Plate XIV, figure 1, but this may in part be due to the imperfection of the border.

The ischia in *Ceratosaurus* are comparatively slender. They project well backward, and for the last half of their length the two are in close apposition. The distal ends are coössified, and expanded, as shown in Plate XI.

The pubes in *Ceratosaurus* have their distal ends coössified, as in all the known *Theropoda*. They project downward and forward, and their position in the pelvis is shown in Plate XI. Seen from the front, they form a Y-shaped figure, which varies in form in different genera. The upper end joins the ilium by a large surface, and the ischium by a smaller attachment. The united distal ends are expanded into an elongate, massive foot, as shown in Plate XI, which is one of the most peculiar and characteristic parts of the skeleton.

The pubes of *Megalosaurus* have not yet been identified, but there can be little doubt that they are of the same general type as in *Ceratosaurus* and *Allosaurus*, shown in Plate XI. The pubes of *Cœlurus* are represented on the same plate. They pertain to a new species, which may be called *Cœlurus agilis*. This animal was at least three times the bulk of the type, the vertebræ of which are represented on Plate XIII. Owen has figured the pubes of another species of this genus, under the name *Poikilopleuron pusillus*, but he regarded the specimen as an "abdominal hæmapophysis and hæmal spine." (Palæontographical Society, vol. xxx, Plate I, 1876.)

The extremely narrow pelvis is one of the most marked features in this entire group, being in striking contrast to the width in this region in the herbivorous forms found with them. If the *Theropoda* were viviparous, which some known facts seem to indicate, one difficulty, naturally suggested in the case of a reptile, is removed.

Another interesting point is, the use of the large foot at the lower end of the pubes, which is the most massive part of the skeleton. The only probable use is, that it served to support the body in sitting down. That some Triassic Dinosaurs sat down on their ischia is proved conclusively by the impressions in the Connecticut River sandstone. In such cases the leg was bent so as to bring the heel to the ground. The same action in the present group would bring the foot of the pubes to the ground, nearly or quite under the center of gravity of the animal. The legs and ischia would then naturally aid in keeping the body balanced. Possibly this position was assumed habitually by these ferocious biped reptiles, in lying in wait for prey.

The Hind Limbs.

Several restorations of the posterior limb of *Megalosaurus* have been attempted, but the imperfect material at hand was not sufficient to ensure entire success. In the restoration of *Allosaurus*, given in Plate XII, figure 2, only the bones found together have been placed in position. The relative proportions of the femur and tibia are shown in this figure, and the general structure of the foot. The astragalus and calcaneum are distinct from the tibia and fibula, as in all the known *Theropoda*, although their coalescence has been regarded as certain in some of the genera.*

In the foot of *Allosaurus fragilis*, represented in Plate XII, no tarsal bones of the second row were found, although the adjoining bones were nearly in their natural position. Whether the former were imperfectly ossified, or lost, in this instance cannot be determined with certainty, but there is evidence of the presence of these bones in several other members of the group. In the present foot, there were three functional digits. The metatarsals are very long, and fitted closely to each other, especially at their upper ends. The phalanges and claws were mostly found near the positions here assigned to them.

* *Compsognathus* is cited as an instance of this union, but in a careful study of the original specimen in Munich, the writer found evidence that the astragalus is distinct, although closely attached to the tibia. Baur has since proved this conclusively (Morpholog. Jahrbuch, VIII). In the *Stegosauridæ* alone, among known Dinosaurs, is the astragalus coössified with the tibia. This, however, is not a character of much importance.

The specimens of *Theropoda* here first described, including the type specimen of *Ceratosaurus nasicornis*, are from the Atlantosaurus beds of the Upper Jurassic, in Colorado, where they were found by Mr. M. P. Felch. The associated fossils are various *Sauropoda*, *Stegosauria*, and *Ornithopoda*, together with Jurassic Mammals.*

Classification.

The main characters of the order *Theropoda*, and of the families now known to belong to it, are as follows:

Order THEROPODA.

Premaxillary bones with teeth. Anterior nares at end of skull. Large antorbital opening. Vertebræ more or less hollow. Fore limbs very small; limb bones hollow. Feet digitigrade; digits with prehensile claws. Pubes projecting downward, with distal ends coössified.

(1.) Family *Megalosauridæ*. Anterior vertebræ convexo-concave; remaining vertebræ bi-concave. Pubes slender. Astragalus with ascending process.

Genera, *Megalosaurus* (*Poikilopleuron*), *Allosaurus*, *Cœlosaurus*, *Creosaurus*, *Dryptosaurus* (*Lælaps*).

(2.) Family *Ceratosauridæ*. Horn on skull. Cervical vertebræ plano-concave, remaining vertebræ bi-concave. Pubes slender. Pelvic bones coössified. Osseous dermal plates. Astragalus with ascending process.

Genus, *Ceratosaurus*.

(3.) Family *Labrosauridæ*. Lower jaws edentulous in front. Cervical and dorsal vertebræ convexo-concave. Pubes slender, with anterior margins united. Astragalus with ascending process.

Genus, *Labrosaurus*.

(4.) Family *Zanclodontidæ*. Vertebræ bi-concave. Pubes broad elongate plates, with anterior margins united. Astragalus without ascending process. Five digits in manus and pes.

Genera, *Zanclodon*, *? Teratosaurus*.

* The presence of various genera of Dinosaurs closely allied to these American forms in essentially one horizon in the Isle of Wight, suggests that the beds in which they occur are not Wealden, as generally supposed, but Jurassic.

(5.) Family *Amphisauridæ*. Vertebræ bi-concave. Pubes rod-like. Five digits in manus, and three in pes.

Genera, *Amphisaurus* (*Megadactylus*), *? Bathygnathus*, *? Clepsysaurus*, *Palæosaurus*, *Thecodontosaurus*.

Sub-order CŒLURIA.

(6.) Family *Cœluridæ*. Vertebræ and bones of skeleton pneumatic. Anterior cervicals convexo-concave; remaining vertebræ bi-concave. Cervical ribs coössified with vertebræ. Metatarsals very long, and slender.

Genus, *Cœlurus*.

Sub-order COMPSOGNATHA.

(7.) Family *Compsognathidæ*. Cervical vertebræ convexo-concave; remaining vertebræ bi-concave. Three functional digits in manus and pes. Ischia with long symphysis on median line.

Genus, *Compsognathus*.

Of these seven well marked families, the *Amphisauridæ* and *Zanclodontidæ* are Triassic, the *Megalosauridæ* are Jurassic and Cretaceous, while the others are all Jurassic alone.

There are still some very diminutive carnivorous Dinosaurs that cannot at present be referred to any of the above families; but this may in part be due to the fragmentary condition in which their remains have been found.

The peculiar orders *Hallopoda* and *Aëtosauria* include carnivorous reptiles which are allied to the *Dinosauria*, but they differ from that group in some of its most characteristic features. In both *Aëtosaurus* and *Hallopus*, the calcaneum is much produced backwards. In the former genus, the entire limbs are crocodilian, and this is also true of the dermal covering. In *Hallopus*, the calcaneum is greatly lengthened, and the whole posterior limb is especially adapted to leaping. In both of these genera, there are but two sacral vertebræ, but this may be the case in true Dinosaurs, especially from the Trias. Future discoveries will probably bring to light intermediate forms between these orders and the typical Dinosaurs.

Yale College, New Haven, March 17, 1884.

EXPLANATION OF PLATES.

PLATE VIII.

FIGURE 1.—Skull of *Ceratosaurus nasicornis*, Marsh; side view.

FIGURE 2.—The same skull; front view.

FIGURE 3.—The same skull; top view.

a, nasal opening; *b*, horn-core; *c*, antorbital opening; *d*, orbit; *e*, lower temporal fossa; *f*, foramen in lower jaw; *t*, transverse bone.

All the figures are one-sixth natural size.

PLATE IX.

FIGURE 1.—Skull and brain-cast of *Ceratosaurus nasicornis*, Marsh; seen from above, one-sixth natural size.

a, nasal opening; *b*, horn-core; *c*, antorbital opening; *c'*, cerebral hemispheres; *d*, orbit; *e*, lower temporal fossa; *f*, frontal bone; *h*, supra-temporal fossa; *j*, jugal bone; *m*, maxillary bone; *m'*, medulla; *n*, nasal bone; *oc*, occipital condyle; *ol*, olfactory lobes; *pf*, pre-frontal bone; *pm*, pre-maxillary bone; *q*, quadrate bone; *qj*, quadrato-jugal bone.

FIGURE 2.—Brain-cast of same skull; side view. One-fourth natural size.

c, cerebral hemispheres; *cb*, cerebellum; *m*, medulla; *ol*, olfactory lobes; *on*, optic nerve; *op*, optic lobe; *p*, pituitary body.

FIGURE 3.—Right pre-maxillary bone of *Creosaurus atrox*, Marsh; front view; one-sixth natural size.

2*a*, lateral view, showing outer side; 2*b*, lateral view, showing inner surface.

FIGURE 4.—Left dentary bone of *Labrosaurus ferox*, Marsh; superior view; one-sixth natural size.

FIGURE 5.—The same bone; lateral view, outer side.

FIGURE 6.—The same bone; lateral view, inner side.

PLATE X.

FIGURE 1.—Atlas of *Ceratosaurus nasicornis*, Marsh.

FIGURE 2.—Axis of *Ceratosaurus nasicornis*.

FIGURE 3.—Third vertebra of *Ceratosaurus nasicornis*.

a, side view; *b*, front view; *c*, posterior view; *d*, top view; *e*, inferior view.

FIGURE 4.—Sixth vertebra of *Ceratosaurus nasicornis;* side view.

FIGURE 5.—Dorsal vertebra of *Ceratosaurus nasicornis;* side view.

FIGURE 6.—Fifth caudal vertebra of same species, with chevron in natural position; side view.

All the figures are one-sixth natural size.

PLATE XI.

FIGURE 1.—Pelvis of *Ceratosaurus nasicornis*, Marsh; side view, seen from the left.

FIGURE 2.—Pelvis of *Allosaurus fragilis*, Marsh; the same view.

a, acetabulum; *il*, ilium; *is*, ischium; *p*, pubis.

Both figures are one-twelfth natural size.

FIGURE 3.—Pubes of *Cœlurus agilis*, Marsh.

a, side view; *b*, front view; *c*, foot, or distal end; one-fourth natural size.

PLATE XII.

FIGURE 1.—Bones of left fore leg of *Allosaurus fragilis*, Marsh.

FIGURE 2.—Bones of left hind leg of *Allosaurus fragilis*.

Both figures are one-twelfth natural size.

PLATE XIII.

FIGURE 1.—Cervical vertebra of *Cœlurus fragilis*, Marsh; front view.

1*a*, side view; 1*b*, transverse section of same vertebra.

FIGURE 2.—Dorsal vertebra of *Cœlurus fragilis*; front view.

2*a*, side view; 2*b*, transverse section of same.

FIGURE 3.—Caudal vertebra of *Cœlurus fragilis*; front view.

2*a*, side view; 2*b*, transverse section of same; *a*, anterior; *p*, posterior; *c*, cavity; *f*, lateral foramen; *nc*, neural canal; *r*, coössified rib; *s*, neural spine; *z*, anterior zygapophysis; *z'*, posterior zygapophysis.

All the figures are natural size.

PLATE XIV.

FIGURE 1.—Left ilium of *Creosaurus atrox*, Marsh; seen from the left.

FIGURE 2.—The same, seen from below; both one-tenth natural size.

a, anterior, or pubic, articulation; *b*, posterior, or ischiadic, articulation.

FIGURE 3.—Lumbar vertebra of *Creosaurus atrox*; front view.

FIGURE 4.—The same; side view, from the left; both one-sixth natural size.

a, anterior articular face; *p*, posterior articular face; *s*, neural spine; *d*, diapophysis; *z*, anterior zygapophysis; *z'*, posterior zygapophysis.

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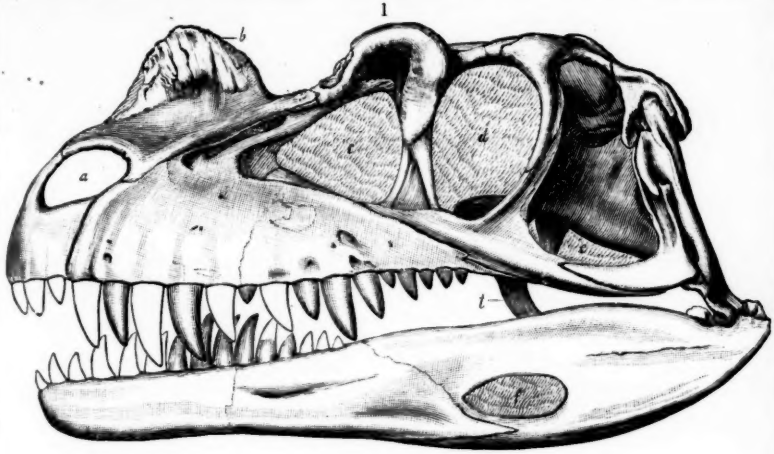

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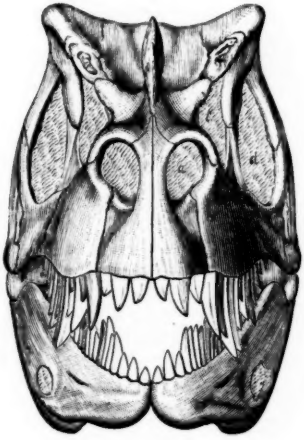

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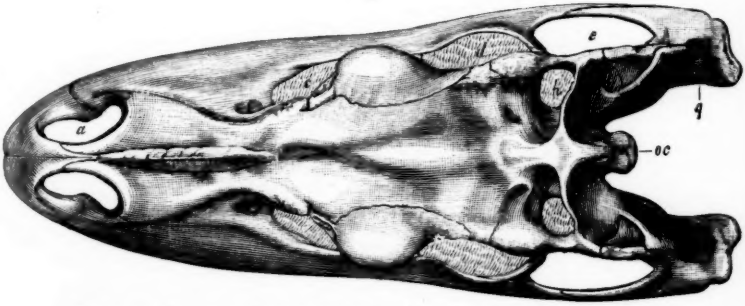
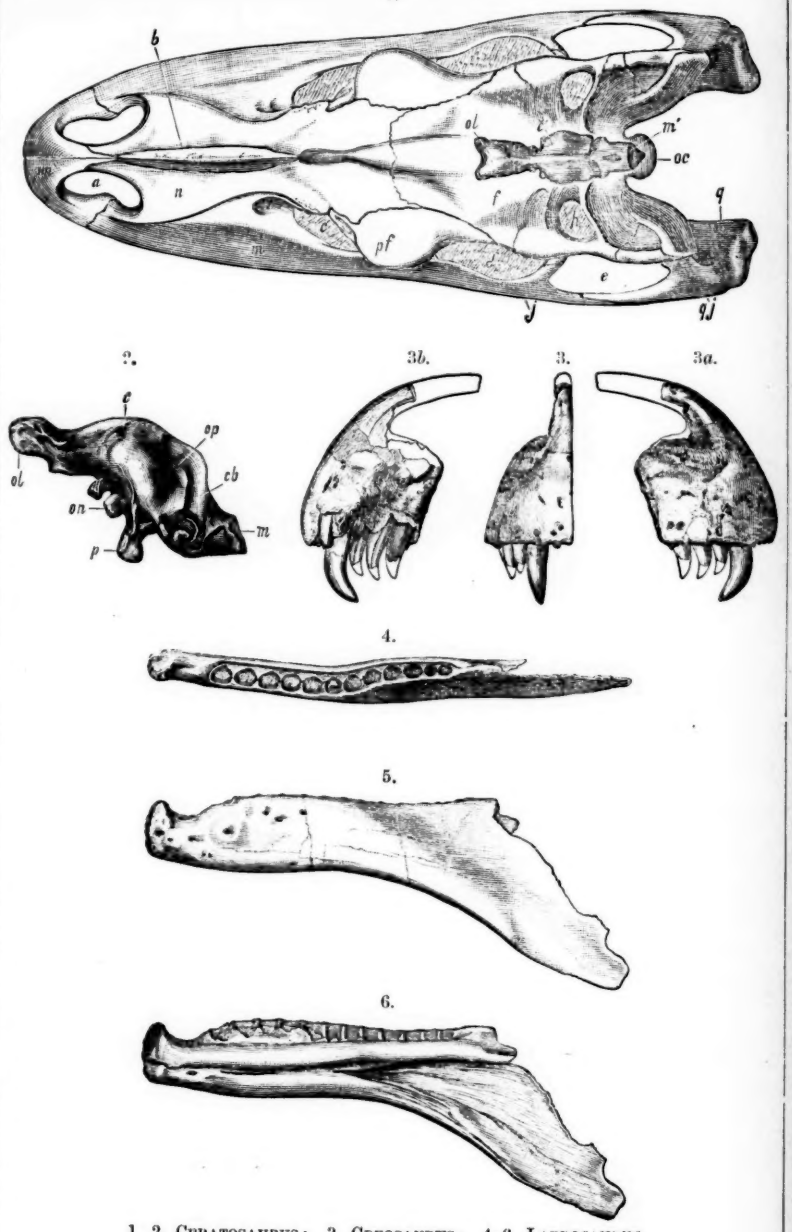
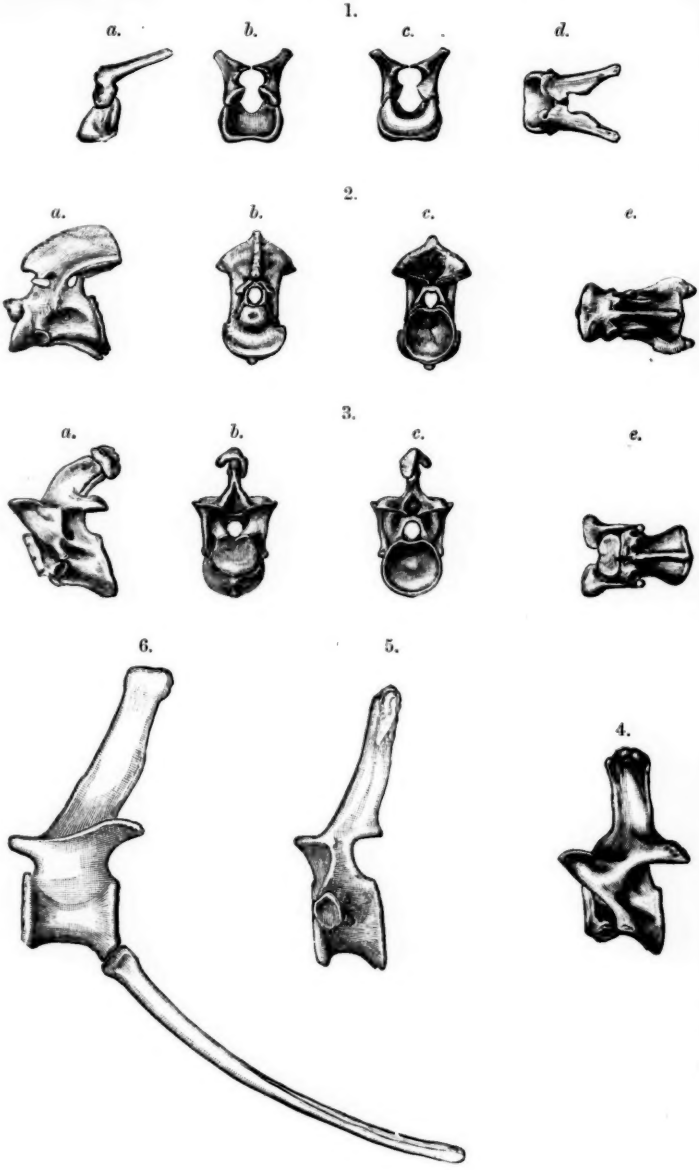


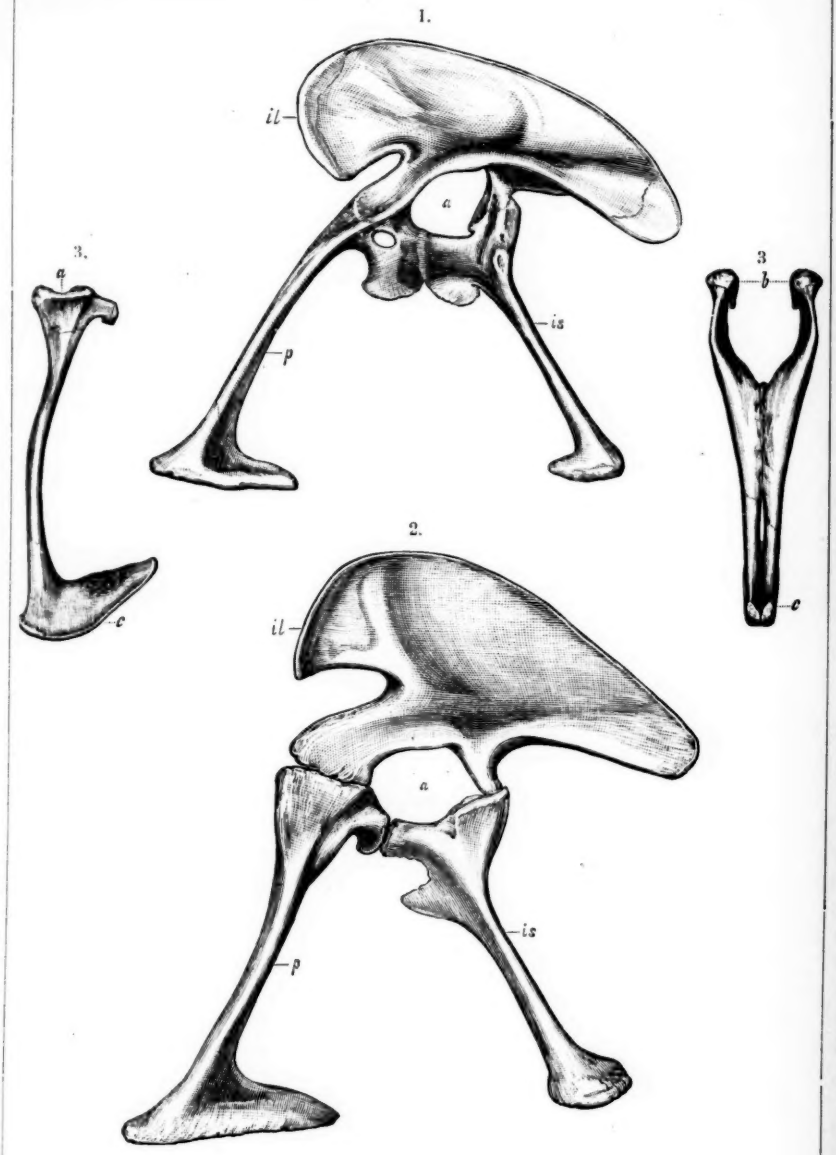
SKULL OF CERATOSAURUS NASICORNIS, Marsh. One-sixth natural size.



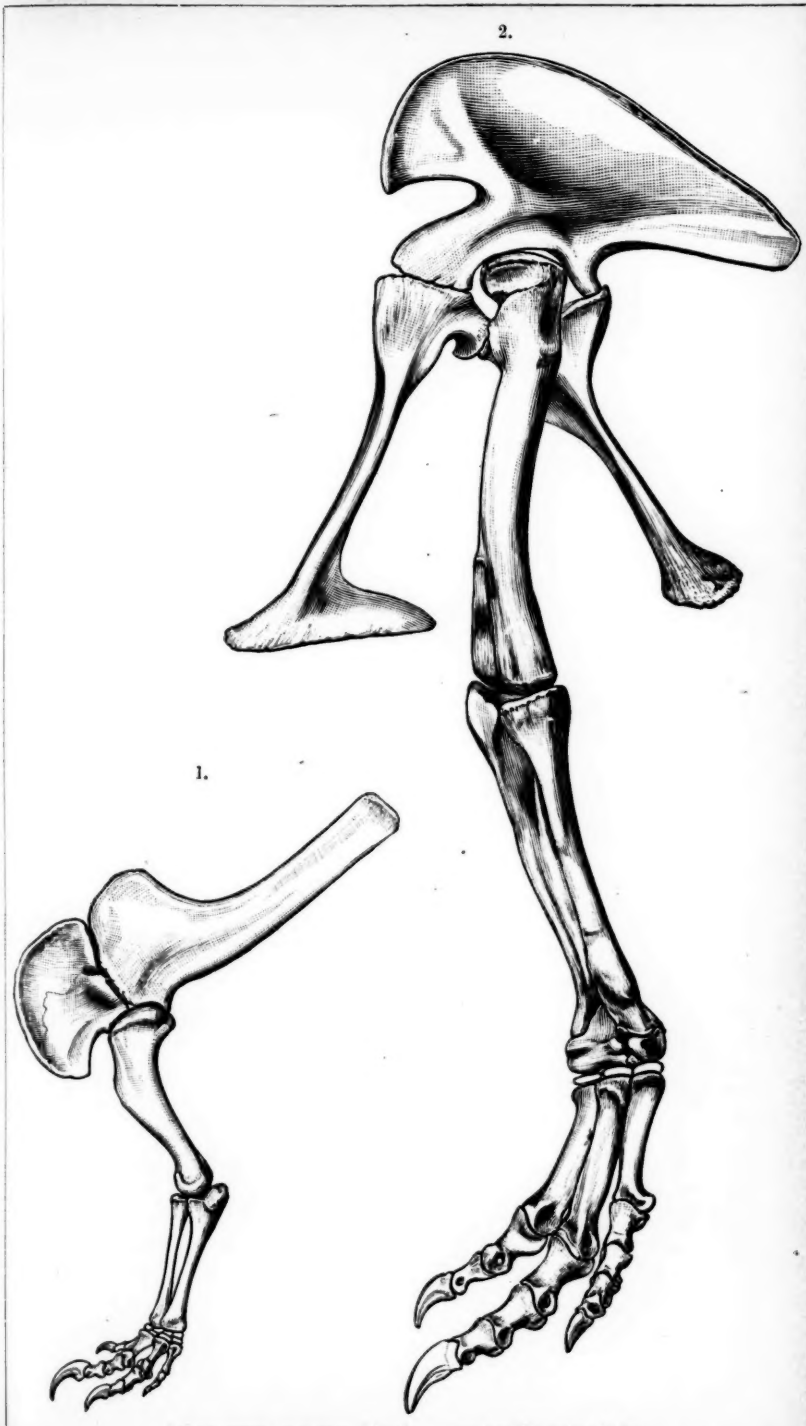
1, 2, CERATOSAURUS; 3, CREOSAURUS; 4–6, LABROSAURUS.



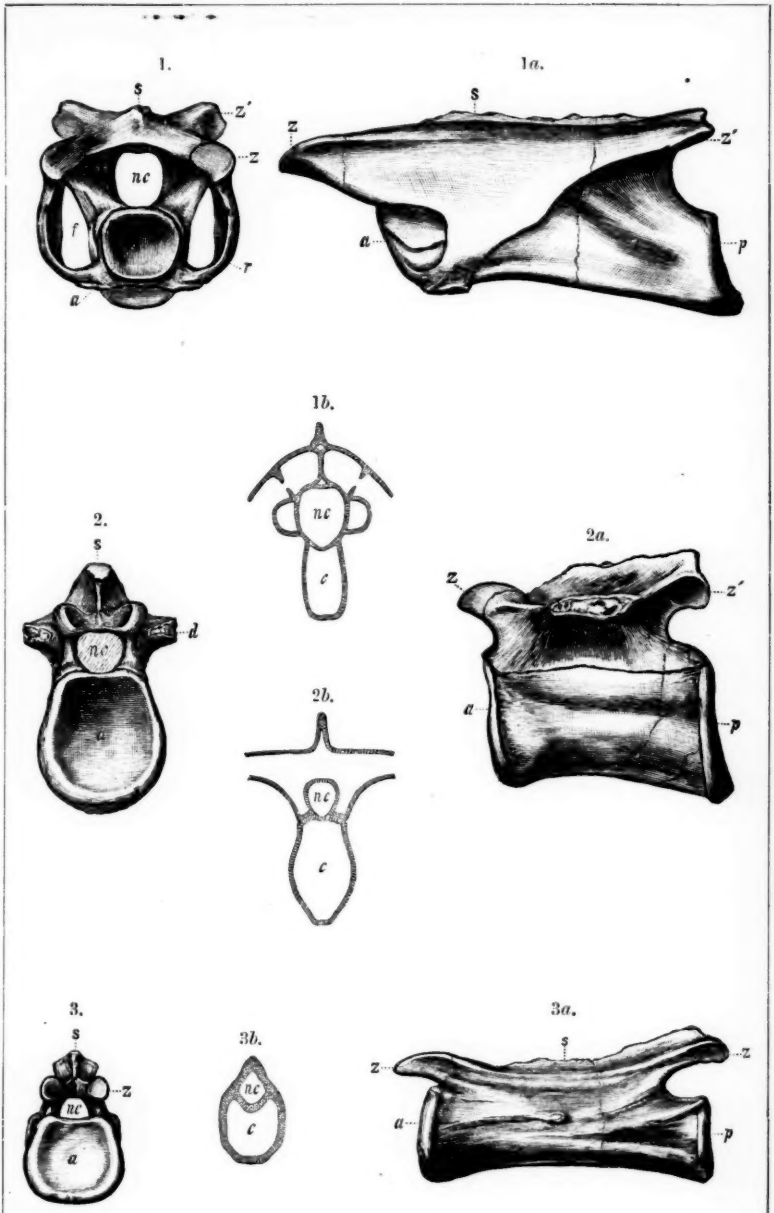
VERTEBRÆ OF CERATOSAURUS NASICORNIS, Marsh. One-sixth natural size.



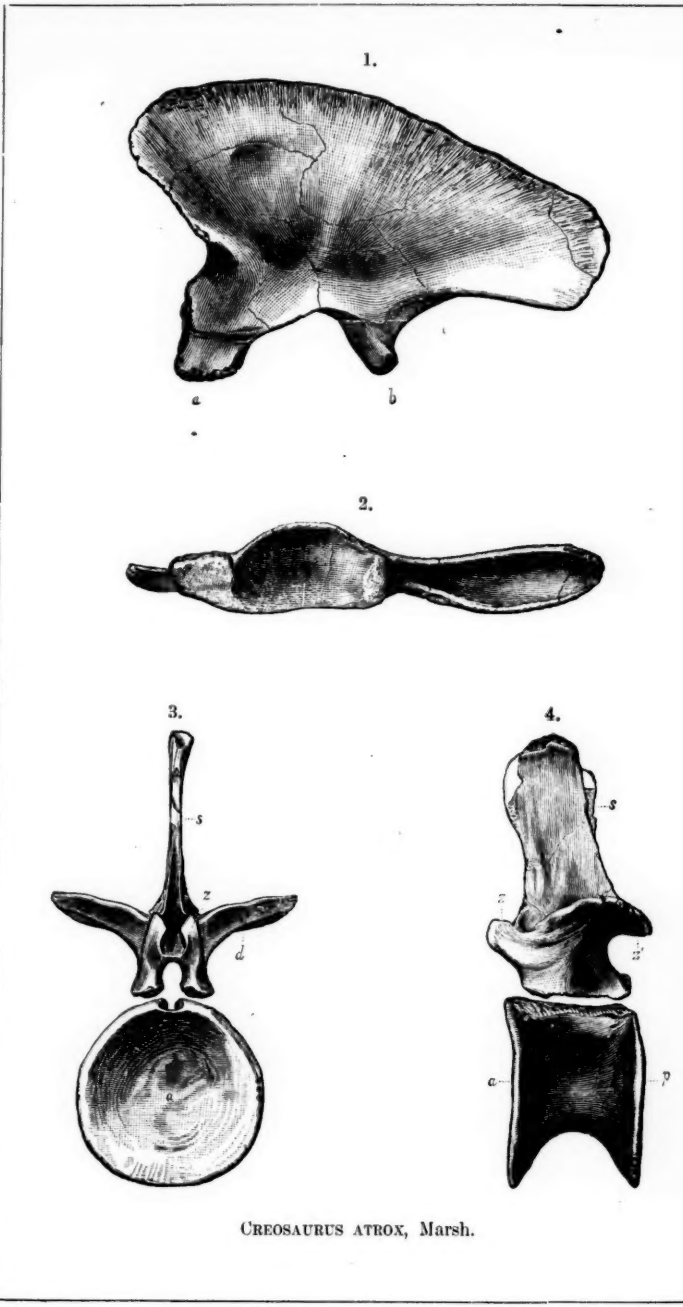
1, Ceratosaurus; 2, Allosaurus; 3, Cœlurus.



ALLOSAURUS FRAGILIS, Marsh. One-twelfth natural size.



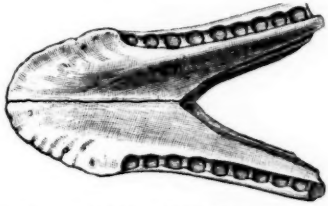
VERTEBRÆ OF CŒLURUS FRAGILIS, Marsh. Natural size.



CREOSAURUS ATROX, Marsh.

Art. XXXIX.—*A new order of extinct Jurassic Reptiles* (Macelognatha); by O. C. Marsh.

A new type of reptilian life is represented in the Yale Museum by various remains, the most characteristic of which are the two dentary bones of the lower jaws. These bones resemble in many respects the corresponding parts of a Turtle, but are broader, and more nearly horizontal. The jaws were evidently covered with a horny beak in front, but further back they contained teeth. The edentulous portion is flat and thin, and nearly horizontal. The two rami meet in nearly the same plane, and are united at the symphysis by a close suture. The form and general characters of these specimens are represented in the cut below.



Jaws of *Macelognathus vagans*, Marsh. Seen from above. One-half natural size.

The teeth were implanted in distinct sockets, in front, but further back, the walls between them become thinner, and a groove appears to gradually take their place. The form of the teeth cannot be determined from the present specimen.

The remains found with these jaws were mostly Chelonian, but none were associated with them in such position as to warrant the conclusion that they pertained to the same animal.

These fossils indicate a new order of reptiles, which may be called the *Macelognatha*, and the family, *Macelognathidæ*. The genus and species may be termed *Macelognathus vagans*.

These jaws are too solid and massive for Birds or Pterodactyles. With Serpents and Lizards they have evidently only remote affinities. The close union of the rami by suture separates them from the Dinosaurs, and the endentulous beak, from Crocodiles. So far as now known, they appear to be nearest allied to the Chelonia, although Turtles without teeth occur in the same strata with them.

The geological horizon of these peculiar remains is in the Atlantosaurus beds of the Upper Jurassic. The locality is in Wyoming Territory.

Yale College, March 21st, 1884.